पढ़े और सीखें योजना

समुद्र
कुबेर का एक भंडार

प्रभात नाथ मुकर्जी

विभागीय सहयोग
राम दुलार शुक्ल

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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प्रकाशन सहयोग

सी.एन.राव *अध्यक्ष प्रकाशन विभाग*

पूरन मल *मुख्य संपादक*
ओम प्रकाश *संपादन सहायक*

यू. प्रभाकर राव *मुख्य उत्पादन अधिकारी*
डी.साईं. प्रसाद *उत्पादन अधिकारी*
विकास ब. मेश्राम *सहायक उत्पादन अधिकारी*
राजेश पिप्पल *उत्पादन सहायक*

एन.सी.ई.आर.टी. के प्रकाशन विभाग के कार्यालय

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मुख पृष्ठ : गहरे समुद्र से तलछट उठायी जा रही है।
पश्च पृष्ठ : समुद्र तल से एकत्र की गई फास्फोराइट पिंडिकाएँ।

रु. 20-00

प्रकाशन विभाग में सचिव, राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्, श्री अरविंद मार्ग, नई दिल्ली 110016 द्वारा प्रकाशित तथा ज़ूम डेस्कटॉप प्रिंटर्स, 1899, उदय चन्द मार्ग, कोटला मुबारकपुर, नई दिल्ली 110 003 द्वारा लेज़र कंपोज होकर बंगाल ऑफसेट वर्क्स, 335, खजूर रोड, करौल बाग, नई दिल्ली 110005 द्वारा मुद्रित।

प्राक्कथन

शिक्षा का मुख्य उद्देश्य मनुष्य को बेहतर इंसान बनाना है। शिक्षा शारीरिक, मानसिक, भावनात्मक व नैतिक दिशा में मनुष्य का विकास करके उसे एक सम्पूर्णता प्रदान करती है। हमारी शिक्षा व्यवस्था में ऐसा तभी संभव हो पाएगा, जब बच्चों में पूर्व-प्राथमिक व प्राथमिक स्तर से ही ऐसे मूल्यों की पौध रोपी जाए कि वे बौद्धिक और कल्पनाजन्य क्षमताओं का विकास करना सीखने लगें।

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद् (एन.सी.ई.आर.टी.) बच्चों में अध्ययन की क्षमता व रुचि दोनों का ही विकास करने के लिए सदा तत्पर रही है और समय-समय पर इस क्षेत्र में विभिन्न प्रयास व नए-नए प्रयोग करती रहती है। पाठ्यक्रम में निर्धारित पुस्तकों के प्रकाशन से इतर परिषद् ने बच्चों में अध्ययन-प्रवृत्ति के विकास के लिए समय-समय पर पूरक अध्ययन सामग्री तथा उसके अंतर्गत प्रयोगात्मक स्तर पर कई पुस्तक-मालाएँ व परियोजनाएँ शुरू की हैं। इन सभी प्रयासों का मूल उद्देश्य है बच्चों की पुस्तकों से दोस्ती कराना।

पूरक अध्ययन सामग्री के प्रकाशन को इस विचार ने जन्म दिया कि बच्चों को पाठ्यपुस्तकों की एकरसता से इतर कुछ ऐसी अध्ययन सामग्री भी दी जानी चाहिए जो कथ्य और कलेवर दोनों ही पक्षों में समृद्ध हो। साथ ही परोक्ष रूप से उन तक वांछित मानवीय मूल्य भी पहुँचाती हो।

लगभग 30 वर्षों से पूरक अध्ययन की पुस्तकों के प्रकाशन का काम जारी रखते हुए परिषद् में इस क्षेत्र में कुछ और अधिक करने की ललक थी और इसी का परिणाम है हमारी **पढ़ें और सीखें** परियोजना। इसके अंतर्गत प्रकाशित पुस्तकों के माध्यम से यह कोशिश की गई है कि बच्चे इस दुनिया में बसी हुई अनेक **अनजान दुनियाओं** से भी परिचित हों तथा उन्हें अपने भीतर के संसार को जानने का भी मौका मिले। उनमें पुस्तकों के प्रति अपनापन व लगाव उपजे।

इन पुस्तकों में कथा साहित्य, भारतीय संस्कृति और इतिहास, विभिन्न महापुरुषों की जीवनियों व आत्मकथाओं आदि से लेकर विज्ञान के क्षेत्र में हो रहे आधुनिकतम आविष्कारों व विकासकारी गतिविधियों तथा जनसंख्या शिक्षा तक का फैलाव समेटा गया है। पुस्तकों के माध्यम से अपने बाल

व किशोर पाठकों को परिषद् सामाजिक जागरुकता, धर्म-निरपेक्षता और वैज्ञानिक मानवतावाद सरीखे मूल्य भी दे रही है।

पढ़ें और सीखें पुस्तक-माला के अंतर्गत पाठ्यक्रम की पुस्तकों से कुछ हट कर तैयार की जाने वाली विज्ञान की पुस्तकों का उद्देश्य है पाठकों को वैज्ञानिक विषयों की सही जानकारी देना तथा उनमें वैज्ञानिक अभिरुचि का विकास करना। आशा है **श्री प्रभात नाथ मुकर्जी** द्वारा लिखित प्रस्तुत पुस्तक **समुद्र-कुबेर का एक भंडार** हमारे पाठकों के लिए आनंदप्रद व उपयोगी सिद्ध होगी।

पढ़ें और सीखें पुस्तक-माला के अंतर्गत प्रकाशित पुस्तकों को और भी उपयोगी बनाने की दिशा में दिए गए हर सुझाव का परिषद् स्वागत करेगी।

अशोक कुमार शर्मा
निदेशक
नई दिल्ली — राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्

दो शब्द

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद् (एन.सी.ई.आर.टी.) की पढ़ें और सीखें योजना के अंतर्गत यह एक छोटा-सा प्रयास है। जब परिषद् के निदेशक ने मुझे इस दिशा में विज्ञान के विषयों का कार्यभार संभालने के लिए आमंत्रित किया तो अपने वैज्ञानिक मित्रों की अतिव्यस्तता के कारण यह उत्तरदायित्व स्वीकार करने में मुझे संकोच था।

इस दिशा में मेरा प्रयास रहा है कि विज्ञान के विभिन्न विषयों के जाने-माने विद्वानों को इस सराहनीय कार्य के लिए निमंत्रित कर सकूँ। ऐसा मेरा विश्वास है कि खोज और अनुसंधान की आनंदपूर्ण अनुभूतियों वाले वैज्ञानिक ही अपने आनंद की एक झलक बच्चों तक पहुँचा सकते हैं। मैं उनका हृदय से आभारी हूँ कि उन्होंने अंकुरित होने वाली पीढ़ी के लिए अपने बहुमूल्य समय में से कुछ क्षण निकालने का प्रयास किया। बच्चे राष्ट्र की सब से बहुमूल्य और महत्वपूर्ण निधि हैं और मेरे लिए यह किंचित आश्चर्य और संतोष की बात है कि हमारे इतने लब्धप्रतिष्ठ और अत्यंत व्यस्त वैज्ञानिक बच्चों के लिए थोड़ा परिश्रम करने के लिए सहर्ष मान गए हैं। मैं सभी वैज्ञानिक मित्रों के प्रति हृदय से आभारी हूँ।

इन पुस्तकों की तैयारी में हमारा मुख्य ध्येय रहा है कि विषय ऐसी शैली में प्रस्तुत किया जाए कि बच्चे स्वयं इसकी ओर आकर्षित हों, साथ ही भाषा इतनी सरल हो कि बच्चों को इनके अध्ययन से विज्ञान के गूढ़तम रहस्यों को समझने में कोई कठिनाई न हो। इन पुस्तकों के पढ़ने से उनमें अधिक पढ़ने की रुचि पैदा हो और उनके नैसर्गिक कौतूहल में वृद्धि हो जिससे ऐसे कौतूहल और उसके समाधान के लिए स्वप्रयत्न उनके जीवन का एक अंग बन जाए।

यह योजना राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद् (एन.सी.ई.आर.टी.) के निदेशक की प्रेरणा से चल रही है। मैं उन्हें इसके लिए बधाई और धन्यवाद देता हूँ।

श्री प्रभात नाथ मुकर्जी ने 'समुद्र कुबेर का एक भण्डार' पुस्तक लिखने के लिए मेरा अनुरोध स्वीकार किया जिसके लिए मैं उनका हृदय से आभारी हूँ। परिषद् के विज्ञान एवं गणित शिक्षा विभाग के प्रो. रामदुलार शुक्ल विज्ञान की पुस्तकों के लेखन से संबंधित योजना के संयोजक एवं

संपादक हैं और बहुत परिश्रम और कुशलता से अपना कार्य कर रहे हैं। प्रो. अमरनाथ महेश्वरी **पढ़ें और सीखें** योजना के संचालक हैं। मैं इन दोनों को हृदय से धन्यवाद देता हूँ।

आशा है कि ऐसी पुस्तकों से हमारी नई पीढ़ी की वैज्ञानिक मानसिकता का शुभारंभ बाल्यकाल ही में हो सकेगा और विज्ञान के नवीनतम ज्ञान के साथ ही साथ उन्हें अपने देश की प्रगति एवं वैज्ञानिकों के कार्य की झलक मिल सकेगी। उनमें अपने राष्ट्र के प्रति गौरव की भावना का भी सृजन होगा।

रामचरण मेहरोत्रा
अध्यक्ष
'पढ़ें और सीखें योजना'
(विज्ञान)

आमुख

पढ़ें और सीखें योजना के अंतर्गत अब तक अनेक पुस्तकें तैयार की जा चुकी हैं। इस योजना के अंतर्गत भौतिकी, रसायन, गणित, पर्यावरण, अंतरिक्ष एवं ब्रह्मांड विज्ञान, नाभिकीय एवं सौर ऊर्जा, आयुर्विज्ञान, समुद्र विज्ञान, राकेटरी, कम्प्यूटर, बायोटेक्नालोजी, इंजीनियरिंग आदि जैसे विज्ञान के विभिन्न क्षेत्रों में पुस्तकों का निर्माण हुआ है। विज्ञान के अन्य बहुत से नये क्षेत्रों में पुस्तकों का लिखना जारी है। विज्ञान के क्षेत्र में तैयार की जाने वाली इन पुस्तकों के लेखन में हमारे देश के जाने माने वैज्ञानिक सक्रिय योगदान दे रहे हैं और वे अपनी वैज्ञानिक अनुभूतियों को सरल एवं सुरुचिपूर्ण भाषा में बच्चों के लिए प्रस्तुत कर रहे हैं। देश के इन लब्धप्रतिष्ठ वैज्ञानिकों को योजना में सम्मिलित करने का मुख्य उद्देश्य यह है कि इन पुस्तकों में लिखी गई विषयवस्तु प्रामाणिक होगी तथा हमारे बच्चे यह महसूस करेंगे कि देश के जाने माने वैज्ञानिक उनके लिए उनके स्तर पर उतरकर विज्ञान के गूढ़तम रहस्यों को सुंदर एवं सरल भाषा में प्रस्तुत करने के लिए कृत संकल्प हैं। इससे बच्चों को, जो हमारे भावी वैज्ञानिक हैं, विज्ञान के क्षेत्र में बहुत ही बड़ा प्रोत्साहन मिलेगा। विज्ञान की इन पुस्तकों के द्वारा हमें पूर्ण आशा है कि बच्चों को आधुनिकतम वैज्ञानिक विषयों की सही जानकारी मिलेगी, साथ ही उनमें एक वैज्ञानिक मानसिकता भी पैदा होगी।

प्रस्तुत पुस्तक **समुद्र-कुबेर का एक भंडार** के लेखन के लिए **श्री प्रभात नाथ मुकर्जी** ने हमारा निमंत्रण स्वीकार किया जिसके लिए हम उनके अत्यन्त आभारी हैं। इस योजना के अंतर्गत तैयार हो रही विज्ञान की पुस्तकों के लेखन का मार्गदर्शन दिल्ली विश्वविद्यालय के भूतपूर्व कुलपति प्रो. रामचरण मेहरोत्रा कर रहे हैं। विज्ञान की पुस्तकों के लेखन के संयोजन एवं अंतिम संपादन आदि का दायित्व हमारे विज्ञान एवं गणित शिक्षा विभाग के प्रो. राम दुलार शुक्ल वहन कर रहे हैं।

मैं प्रो. रामचरण मेहरोत्रा और अपने सहयोगी प्रो. राम दुलार शुक्ल को हार्दिक धन्यवाद एवं बधाई देता हूँ।

इस पुस्तक को इतने अच्छे ढंग से प्रकाशित करने के लिए मैं परिषद् के प्रकाशन विभाग के कार्यकर्ताओं, विशेषकर विभागाध्यक्ष श्री सी.एन. राव और मुख्य संपादक श्री पूरन मल को हार्दिक धन्यवाद देता हूँ।

इस माला की पुस्तकों पर बच्चों, अध्यापकों एवं बच्चों के माता-पिता की प्रतिक्रिया का हम स्वागत करेंगे ताकि इन पुस्तकों को और भी उपयोगी बनाने में हमें सफलता मिल सके।

अमर नाथ महेश्वरी
प्रोफेसर एवं विभागाध्यक्ष
विज्ञान एवं गणित शिक्षा विभाग
राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद

नई दिल्ली
सितम्बर, 1994

लेखक परिचय

श्री प्रभात नाथ मुकर्जी ने कलकत्ता के प्रेसिडेन्सी कालेज से रसायन शास्त्र में प्रथम श्रेणी में एम. एस.सी. की उपाधि प्राप्त करने के पश्चात् कुछ साल तक वहीं (प्रेसिडेन्सी कालेज में) रसायन विभाग में प्रवक्ता के पद पर कार्य करते रहे। वहीं से केंद्रीय सरकार की सेवा में प्रविष्ट हुए। आगे बढ़ते हुए श्री मुकर्जी दिल्ली में स्थित महासागर विकास विभाग (भारत सरकार) के विशेष कार्य अधिकारी नियुक्त हुए और कुछ समय पश्चात् इसी विभाग में संयुक्त सचिव का पद संभाला। महासागर विकास विभाग में कार्यरत रहते हुए इनकी अभिरुचि बहुधात्विक पिंडिकाओं, बहुधात्विक साल्फाइडों, सामुद्रिक जीवित प्राणियों एवं तरंग ऊर्जा आदि परियोजनाओं की ओर बढ़ी। इस संदर्भ में भारत सरकार ने श्री मुकर्जी को विभिन्न देशों जैसे– इंग्लैंड, फ्रांस, नार्वे, फिनलैंड, जर्मनी, स्पेन, मारिशॉस आदि में सरकारी प्रतिनिधि के रूप में भेजा। श्री मुकर्जी कुछ वर्षों के लिये ड्रेजिंग कार्पोरेशन आफ इंडिया के बोर्ड आफ डाइरेक्टर्स एवं इंडियन रेजिस्ट्रार आफ शिपिंग के मैनेजमेंट कमेटी के सदस्य भी रहे।

पढ़ें और सीखें योजना के अंतर्गत बच्चों के लिये हिन्दी में लिखी गई श्री मुकर्जी की पहली पुस्तक थी पेंग्विन के देश में, यह पुस्तक इन्होंने महासागर विकास विभाग के प्रथम सचिव डॉ. सैयद जहूर कासिम के सहयोग से लिखी। इस पुस्तक में इन्होंने नवीनतम महाद्वीप अंटार्कटिका के बारे में एक रुचिकर वर्णन प्रस्तुत किया है। प्रस्तुत पुस्तक समुद्र-कुबेर का एक भंडार में भी मुकर्जी ने महासागर में छिपी हुई बहुमूल्य संपदाओं पर प्रकाश डाला है। आशा है कि यह पुस्तक बच्चों के लिये काफी उपयोगी होगी।

गांधी जी का जन्तर

तुम्हें एक जन्तर देता हूं। जब भी तुम्हें सन्देह हो या तुम्हारा अहम् तुम पर हावी होने लगे, तो यह कसौटी आजमाओ :

जो सबसे गरीब और कमजोर आदमी तुमने देखा हो, उसकी शकल याद करो और अपने दिल से पूछो कि जो कदम उठाने का तुम विचार कर रहे हो, वह उस आदमी के लिए कितना उपयोगी होगा। क्या उससे उसे कुछ लाभ पहुंचेगा ? क्या उससे वह अपने ही जीवन और भाग्य पर कुछ काबू रख सकेगा ? यानि क्या उससे उन करोड़ों लोगों को स्वराज्य मिल सकेगा जिनके पेट भूखे हैं और आत्मा अतृप्त है ?

तब तुम देखोगे कि तुम्हारा सन्देह मिट रहा है और अहम् समाप्त होता जा रहा है।

लेखकीय

भारत प्रमुख तटवर्ती राष्ट्रों में से एक है। सदियों से यहाँ के लोग समुद्री मार्ग से आसपास तथा दूर के देशों में जाकर उनके साथ व्यापार करते थे। भारत के निवासी परिवहन एवं संचार के लिए तथा खाद्य पदार्थों की खोज में निकटवर्ती समुद्रों का उपयोग शताब्दियों से करते आ रहे हैं। तेजी से बढ़ती हुई जनसंख्या की माँग की पूर्ति करने के लिए समुद्री संसाधनों को उपयोग में लाने की आवश्यकता अत्यन्त नाटकीय रूप से आज बढ़ गयी है।

समुद्र कानून पर संयुक्त राष्ट्र समझौते को 30 अप्रैल, 1982 को अपनाया गया। इस समझौते पर भारत सहित 159 देशों ने पहले ही हस्ताक्षर कर दिये हैं और अभी तक लगभग 45 देशों ने इसे अभिपुष्ट कर दिया है। इस समझौते द्वारा स्थापित **नवीन महासागर प्रणाली** (New Ocean Regime) ने विश्व के महासागरों के महत्वपूर्ण भाग को **अनन्य आर्थिक क्षेत्रों** (Exclusive Economic Zone) में बाँट दिया है जहाँ तटीय राज्यों को संसाधनों की खोज और उनके उपयोग एवं अन्य आर्थिक प्रयोजनों के लिए अधिकार प्राप्त हैं।

महासागर संबंधी वैज्ञानिक सर्वेक्षण, अन्वेषण एवं अनुसंधान के महत्व तथा औचित्य को देखते हुए भारत सरकार ने 24 जुलाई, 1981 को महासागर विकास विभाग की स्थापना की। इस विभाग ने 'महासागर नीति वक्तव्य' (Ocean Policy Statement) नामक प्रलेख को अंतिम रूप दिया और यह वक्तव्य संसद के दोनों सदनों में प्रस्तुत किया गया। इस वक्तव्य के अनुसार–

"एक आत्मनिर्भर प्रौद्योगिकीय आधार तैयार करने के लिए सुप्रशिक्षित कार्मिकों की बढ़ी संख्या में जरूरत है।............युवा वैज्ञानिकों, प्रौद्योगिकविदों, इंजीनियरों को महासागर विकास कार्यक्रम में भाग लेने के लिए प्रोत्साहित किया जायेगा.........."

इन सभी तथ्यों को ध्यान में रखते हुए यह आवश्यक प्रतीत होता है कि विभिन्न आयुवर्ग के बच्चों में समुद्र में छिपी हुई सम्पदा तथा उसके सजीव एवं निर्जीव संसाधनों के बारे में दिलचस्पी पैदा की जाए जिससे कि आगे बढ़कर ये बच्चे समुद्र संबंधी विभिन्न विषयों जैसे भौतिक एवं रासायनिक समुद्र विज्ञान, समुद्री जैविकी, समुद्री भूविज्ञान; मौसम विज्ञान में स्नातक या स्नातकोत्तर डिग्री पाकर समुद्र वैज्ञानिक अनुसंधान एवं विकास कार्य में महत्वपूर्ण भूमिका निभा सकें।

मेरे विचार में राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद् (एन.सी.ई.आर.टी.) की महत्वपूर्ण योजना– **पढ़ें और सीखें** ऐसा एक उचित माध्यम होगा जिससे बच्चों को सागर की सम्पदा के बारे में जानकारी दी जाये। आशा है कि इस योजना के अन्तर्गत प्रस्तुत पुस्तक **समुद्र–कुबेर का एक भंडार** इस उद्देश्य को प्राप्त करने में कम से कम कुछ हद तक सफल होगी।

मैं इस पुस्तक के प्रकाशन के लिए **राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्** का आभारी हूँ।

पुस्तक के लेखन का मार्गदर्शन राजस्थान विश्वविद्यालय के डॉ. रामचरण मेहरोत्रा प्रोफेसर–एमेरिटस ने किया है। परिषद् के विज्ञान एवं गणित शिक्षा विभाग के प्रोफेसर राम दुलार शुक्ल ने इस पुस्तक के लिखने एवं संपादन में हर सम्भव सहयोग दिया। मैं इन दोनों के प्रति आभार प्रकट करता हूँ।

मुझे समुद्र विज्ञान संबंधी पुस्तक लिखने में **महासागर विकास विभाग** के पहले सचिव *डॉ. सैयद जहूर कासिम साहब, जो अब योजना आयोग के सदस्य हैं, से प्रेरणा मिली।* मैं उनके प्रति कृतज्ञ हूँ।

मैं महासागर विकास विभाग के श्री भीमसेन राव (*निदेशक*) एवं कुमारी राकेश शर्मा (*सहायक निदेशक*) के नाम का विशेष रूप से जिक्र करना चाहूँगा, जिन्होंने इस पुस्तक के लेखन में बहुत ही मूल्यवान सुझाव दिये हैं।

अन्त में इस पुस्तक के लिखने और आवश्यक सुधार करने में मेरी अनुजवधू श्रीमती उमा चक्रवर्ती और मेरी धर्मपत्नी श्रीमती झरणा मुकर्जी ने जो सहयोग दिया उसके लिए मैं इन दोनों का आभारी हूँ।

आज समुद्र विज्ञान एक नवीनतम विज्ञान के रूप में माना जाता है। इसमें बहुत से तकनीकी शब्द ऐसे हैं जिनका अभी तक हिन्दी में उचित रूपान्तरण नहीं हो पाया है और इस तरह वे प्रचलित शब्द नहीं हो पाए हैं। इसलिए इस पुस्तक में कुछ हिन्दी शब्दों, विशेषतः व्यक्तिवाचक संज्ञाओं के साथ-साथ प्रचलित अंग्रेजी शब्दों को भी व्यवहार में लाया गया है।

प्रभात नाथ मुकर्जी

विषय-सूची

विज्ञान संबंधित मूल्य

जिज्ञासा, ज्ञान-पिपासा, वस्तुनिष्ठता, ईमानदारी व सच्चाई, प्रश्न करने का साहस, क्रमबद्ध तर्क, प्रमाण/सत्यापन के पश्चात स्वीकृति, खुला दिमाग, पूर्णता प्राप्त करने की अभिलाषा तथा मिलजुल कर कार्य करने की भावना आदि विज्ञान संबंधी कुछ आधारभूत मूल्य हैं। इन मूल्यों द्वारा विज्ञान के उन प्रक्रमों को अभिलक्षणित किया जाता है, जो प्रकृति एवं उसकी अपघटनाओं से संबंधित सत्य के अन्वेषण में सहायता प्रदान करते हैं। विज्ञान का उद्देश्य विभिन्न वस्तुओं एवं अपघटनाओं की व्याख्या करना है। अतः विज्ञान सीखने एवं उसका अभ्यास करने के लिए –

* **अपने परिवेश की वस्तुओं तथा घटनाओं के प्रति जिज्ञासु बनें।**
* **प्रचलित विश्वासों एवं मान्यताओं पर प्रश्नचिह्न लगाने का साहस करें।**
* **"क्या", "कैसे" तथा "क्यों" में प्रश्न करें एवं सूक्ष्म प्रेक्षणों, प्रयोगों, परामर्शों, चर्चाओं व तर्कों द्वारा अपना उत्तर प्राप्त करें।**
* **प्रयोगशाला में अथवा उसके बाहर प्राप्त अपने प्रेक्षणों एवं प्रायोगिक परिणामों को सच्चाईपूर्वक लिखें।**
* **आवश्यकता पड़ने पर, प्रयोगों की पुनरावृत्ति सावधानीपूर्वक एवं क्रमबद्ध तरीके से करें, किन्तु किसी भी परिस्थिति में अपने परिणामों में हेरफेर न करें।**
* **तथ्यों, विचार-बुद्धि एवं तर्कों द्वारा अपना मार्गदर्शन करें, पूर्वाग्रहों से ग्रस्त न हों।**
* **अनवरत एवं समर्पित कार्य के द्वारा नई खोजों एवं नए आविष्कारों के लिए उत्कट अभिलाषा रखें।**

अध्याय 1

रामू पुस्तकालय जाता है

आज रामू बहुत खुश था। उसकी वार्षिक परीक्षा का नतीजा निकल चुका था। रामू को आठवीं कक्षा में उत्तीर्ण कर दिया गया था। कक्षा अध्यापिका ने उसकी बहुत प्रशंसा की। उसे शायद एक या दो पुरस्कार भी मिल सकते हैं। परिणाम की घोषणा के पश्चात् कक्षा अध्यापिका ने स्कूल अगले कुछ दिनों के लिए बन्द रखने की घोषणा की।

सुबह से बूंदें पड़ रही थीं। इस समय के लिए यह कुछ अस्वाभाविक मौसम था। यह अप्रैल के महीने के बीच का समय था। चारों ओर घने काले बादल छाये हुए थे। रामू ने सोचा, अच्छा है कि वह पास के किसी स्कूल के पुस्तकालय में जाकर कोई दिलचस्प पुस्तक पढ़कर समय बिताये। ऐसे मौसम में घर जाने का कोई भी मतलब नहीं था क्योंकि घर पहुँचते-पहुँचते वह बारिश में भीग भी सकता था।

आज किस्मत से पुस्तकालय खुला था। पुस्तकालय की अध्यक्ष महोदया रामू को बहुत अच्छी तरह जानती थीं, वे रामू की दिलचस्पी को भी जानती थीं। रामू रोमांचक और अभियानों की पुस्तकें पसन्द करता था। पुस्तकालय की अध्यक्ष महोदया ने उसे **जूल वार्न** (JULES VERNE) की **"ट्वेंटी थाउजेंड लीग्स अण्डर द सी"*** (Twenty Thousand Leagues Under The Sea) शीर्षक पुस्तक पढ़ने के लिए दी जो बहुत रोमांचक और चित्ताकर्षक थी। पुस्तक पढ़ते-पढ़ते रामू ने पाया कि

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* फ्रांस में एक लीग को करीब 2,764 मील अर्थात् 4.4 किलोमीटर की गहराई के बराबर माना जाता था। इसके अनुसार नाटिलास नाम की पनडुब्बी 80,000 किलोमीटर की गहराई तक जा सकती थी। यह लेखक की कल्पना ही थी क्योंकि वास्तव में महासागर की गहराई ज्यादा से ज्यादा 12 किलोमीटर तक पायी जाती है (प्रशान्त महासागर के मेरीयाना ट्रेंच में)।

नाटिलास, जो कि एक पनडुब्बी है, पानी में बहुत नीचे तक जाती है और कभी-कभी यह ऊपर भी आती है। जब नाटिलास सागर के बहुत नीचे डूब जाती है तो कई रंगीन मछलियाँ चारों ओर तैरती हुई दिखाई देती हैं। कुछ पीली, कुछ हरी और कुछ सफेद रंग की। ओह वे क्या हैं? आठ पैरों का जानवर आक्टोपस, समुद्री साँप चारों तरफ मंडरा रहे हैं। खून की प्यासी शार्क मछलियाँ अपने दाँत निकालकर पूँछ हिला रही हैं। कभी-कभी नाटिलास सागर के तट को छूती है। कितनी तरह के बहुमूल्य पत्थर सागर के अंदर चारों तरफ दिखाई देते हैं। विचित्र प्रकार के पौधे सामुद्रिक फूल और कुछ खनिज वस्तुएँ दिखाई देती हैं। ओह, कैसा सुन्दर सागर है! कैसी रंगीन तरंग है! रामू ने अपने आप से कहा, "अगर मैं सागर के बारे में और अधिक जान सकता तो कितना अच्छा होता! सागर के अन्दर का गुप्त रहस्य, स्थल से ज्यादा रोमांचक है। मुझे अवश्य ही इस गुप्त रहस्य और छिपी हुई संपदा के बारे में जानना चाहिए।'' रामू ने पुस्तकालय की अध्यक्ष महोदया से पुस्तकों की एक सूची देने के लिए कहा जो सागर के प्रति उसकी पैदा हुई उत्सुकता को सन्तुष्ट कर सकें। रामू ने बहुत सारी पुस्तकें पढ़ीं किन्तु समुद्र के विषय में उसकी उत्सुकता बढ़ती ही गई। गर्मी की छुट्टियों में रामू ने अनेक पुस्तकों का अध्ययन किया। स्कूल खुलने पर रामू अपनी अध्यापिका से मिला एवं उनसे और अधिक जानकारी के लिए अनेक प्रश्न किये। अगले अध्याय में हम रामू एवं अध्यापिका के बीच हुई बातचीत का विवरण प्रस्तुत करेंगे।

अध्याय 2

सागर का परिचय

(SEA — AN INTRODUCTION)

अध्यापिका कहने लगी– "प्राचीन काल में ग्रीकवासियों का विचार था कि एक नदी पृथ्वी के चारों ओर अनवरत बंहती रहती है। इस काल्पनिक नदी का नाम उन्होंने *औसानास* (Oceanus) दिया, जिसका अर्थ है 'स्वर्ग और पृथ्वी का पुत्र'। बाद में उस पानी का नाम औसानास रखा गया जो धरती के बहुत दूर तक फैला हुआ था। उसके बाद एक और नया नाम दिया गया। ग्रीकवासियों के अनुसार यह (महासागर) हरक्यूलिस के स्तंभ की परिधि के बाहर था और इसे पौराणिक इतिहास के काल्पनिक *एटलांटिस* (Atlantis) के स्थान के आधार पर अतलांटिक महासागर कहा गया। अटलांटिक महासागर, प्रशान्त महासागर (पेसिफिक ओशन), हिन्द महासागर, आर्कटिक और अंटार्कटिक–पांच महासागर हैं। प्रसिद्ध अन्वेषणकारी **फेर्डिनांड मैगेलान्न** (FERDINAND MAGELLAN) के अनुसार प्रशान्त महासागर एक शान्त और स्थिर महासागर है। यह महासागर उनकी यात्रा के दौरान कुछ सप्ताह तक वास्तव में शान्त था। तीसरे महासागर–हिन्द महासागर को, विशाल देश हिन्दुस्तान के नाम पर रखा गया। इस महासागर की उत्तरी सीमा हिन्दुस्तान तक है। यह जलराशि जो उत्तरी ध्रुव के चारों ओर है आर्कटिक महासागर के नाम से प्रसिद्ध है। दक्षिण ध्रुवीय महाद्वीप, जिसे अंटार्कटिका कहा जाता है, के चारों ओर फैले हुए जलक्षेत्र को अंटार्कटिक महासागर कहते हैं।

हजारों साल से मनुष्य ने महासागर के ऊपर अपनी नौका चलायी है। दुनियाँ के सभी स्थल भागों की उसने खोज की है। आज जब वह चाँद पर भी पहुँच चुका

है, समुद्र के बारे में उसकी जानकारी बहुत ही सीमित है। समुद्र सदियों तक रहस्यमय और भय का कारण बना रहा है।

धरती पर समुद्र लगभग 36 करोड़ वर्ग किलोमीटर सतह को घेरता है, अर्थात् धरती की 70.8% सतह पर जल ही जल है। लेकिन जल का वितरण बराबर नहीं है। 43.00% उत्तरी गोलार्द्ध में और 57.00% दक्षिणी गोलार्द्ध में है। प्रशान्त महासागर सबसे विशाल महासागर है। इसका क्षेत्रफल, जो लगभग सोलह करोड़ वर्ग किलोमीटर है, सम्पूर्ण पृथ्वी के भू-भाग के क्षेत्रफल से अधिक है। इसकी औसत गहराई लगभग 4.3 किलोमीटर है। परन्तु इसके कुछ भाग ऐसे भी हैं जो इससे भी अधिक गहरे हैं। 23 दिसम्बर, 1960 को संयुक्त राष्ट्र अमेरीका के **बेथीस्केप ट्राइस्ते** (Bathyscape Trieste) नामक पनडुब्बी, **मेरीयाना ट्रेंच** (Marianas Trench) की गहराई (जो 11 किलोमीटर है) को छूने में सफल हुई।

अटलांटिक महासागर लगभग आठ करोड़ वर्ग किलोमीटर अर्थात् प्रशान्त महासागर के आधे हिस्से को घेरता है। इसकी औसत गहराई 4164 मीटर है। **'प्यूरटो रिको ट्रेंच'** में इसकी गहराई 9043 मीटर है।

हिन्द महासागर, क्षेत्रफल की दृष्टि से, कुछ हद तक छोटा है। इसका क्षेत्रफल करीब सात करोड़ वर्ग किलोमीटर और औसत गहराई लगभग 3900 मीटर है। इसकी अधिकतम गहराई 7000 मीटर है जो कि जावा के दक्षिण में **सूंडा ट्रेंच** (Sunda Trench) में है।

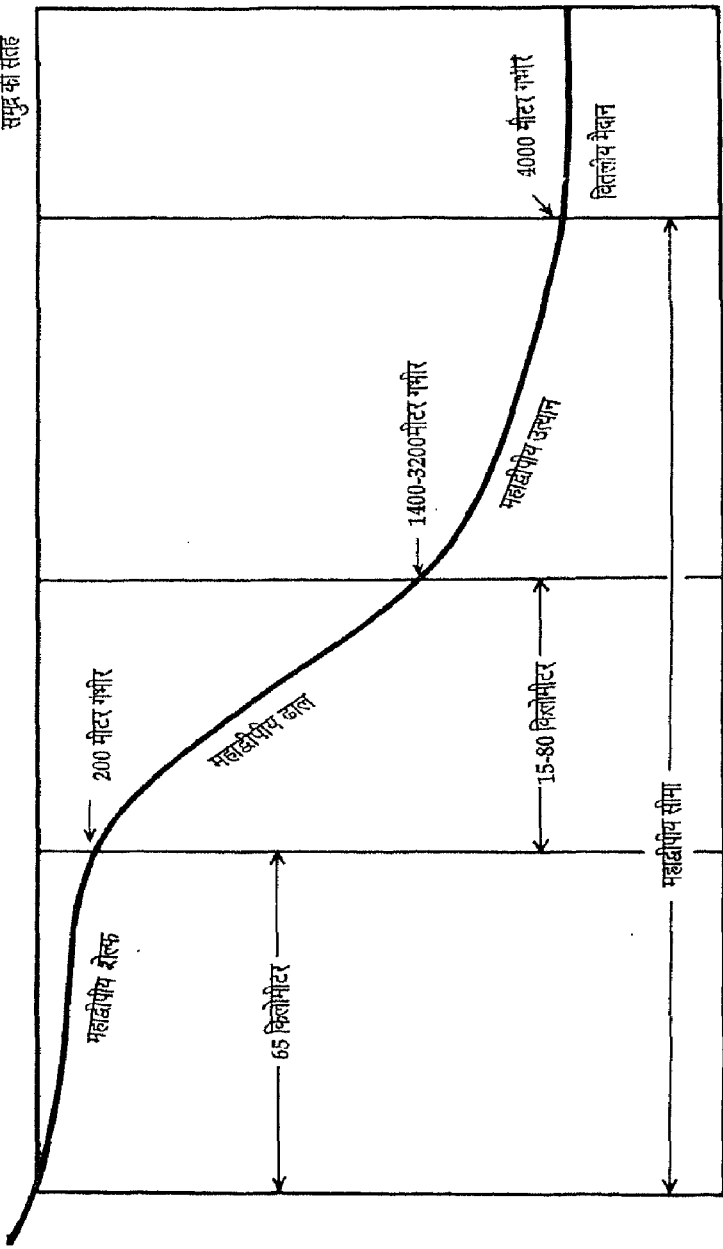
आर्कटिक एक छोटा महासागर है जो कि लगभग 1.4 करोड़ वर्ग किलोमीटर स्थान में फैला हुआ है। इसकी औसत गहराई केवल 1200 मीटर है। इसकी अधिकतम गहराई 5355 मीटर है।

महाद्वीपीय मुख्य भूमि के नजदीक चारों ओर जल प्राय: उथला होता है। ज्वार चिन्ह से 200 मीटर की गहराई तक फैले हुए समुद्री क्षेत्र को **महाद्वीपीय शेल्फ** (Continental Shelf) कहा जाता है। **महाद्वीपीय शेल्फ** क्षेत्रफल की दृष्टि से महासागर का 8% भाग तक बनता है। परन्तु इसकी चौड़ाई में काफी परिवर्तन होता रहता है। कहीं पर यह 16 किलोमीटर चौड़ा है तो कहीं पर यह 1300 किलोमीटर

है। किनारों से **महाद्वीपीय ढाल** (Continental Slope) '15 में से एक' से लेकर '2 में से एक' तक के अनुपात में सतह पर गिरती है। इसका कारण यह है कि पृथ्वी के टूटे-फूटे धरती के टुकड़े गिरकर इसको समान करते रहते हैं और समुद्र पृष्ट और ढाल के काफी भाग में लगातार टूटती दरारें खड्डे आदि बनते रहते हैं। महाद्वीपीय शेल्फ के बाहरी किनारे से महाद्वीपीय ढाल शुरु होती है जो सामान्यत: 1400 से 3200 मीटर तक गहरी होती है (चित्र 1)। कुछ हद तक हम इसे काफी खड़ी ढाल कह सकते हैं और यह सागर का बेसिन बनाता है। इसका ऊपरी हिस्सा, जो 200 मीटर गहरा है और महाद्वीपीय शेल्फ का बाहरी किनारा है, कभी-कभी **महादेश के किनारे** (Continental Margin) के नाम से भी जाना जा सकता है। महाद्वीपीय ढाल के नीचे **महाद्वीपीय उत्थान** (Continental Rise) शुरु होता है। यह 4000 मीटर नीचे जाता है। उसके आगे **वितलीय मैदान** (Abyssal Plain) शुरु हो जाता है।

पहले यह समझा जाता था कि 2000 मीटर की गहराई के बाद समुद्रतल की ढाल अदृश्य हो जाती है। ऐसा पाया जाता है कि इसका अधिकतर भाग धरती की तरह समतल नहीं है। समुद्र के अंदर अधिकतर स्थान असमतल है और उनके बारे में स्पष्ट रूप से कहा नहीं जा सकता।''

रामू ने यहाँ तक अध्यापिका की बात ध्यानपूर्वक सुनी और वह इस बारे में सोचता रहा। दूसरे दिन वह अपने भूगोल के अध्यापक के पास पहुँचा जो बड़ी कक्षाओं में पढ़ाते थे। भूगोल के अध्यापक द्वारा थोड़ा सा समझाए जाने पर रामू का ज्ञान समुद्र विज्ञान की ओर धीरे-धीरे बढ़ गया।

भूगोल के अध्यापक ने कहा, "पुराने जमाने में दुनियाँ की आकृति के बारे में अनेक अद्‌भुत धारणाएँ थीं। **सेविले के इसीडोर** (ISIDORE OF SEVILLE) ने सातवीं शताब्दी में एक चक्र के ऊपर पृथ्वी का नक्शा बनाया जिसमें उसने दिखाया कि पृथ्वी पानी के वृत्त से घिरी हुई है। यूनानी महाकवि **होमार** (HOMER) के अनुसार पृथ्वी तीन भाग में विभक्त थी और इन्हीं महासागरों के वृत्त से घिरी हुई थी। पूर्वी भाग में एशिया, और पश्चिमी दो भाग के उत्तर भाग में यूरोप तथा दक्षिण में अफ्रीका। इसके बाद, शताब्दियों तक बहुत ही कम प्रगति हुई। पुर्तगाल के राजकुमार प्रिन्स

चित्र 1 : महाद्वीपीय सीमा

हेनरी, जो नेवीगेटर (नाविक) के नाम से परिचित थे, के जीवनकाल में सामुद्रिक खोज को काफी प्रोत्साहन दिया गया। 1486 में **बारथोलोमी डियास** (BARTHOLOMEW DIAZ) ने *केप ऑफ गुड होप* (Cape of Good Hope) के चारों तरफ परिक्रमा करके अटलांटिक और हिन्द महासागर के बीच के सम्पर्क को ढूंढ निकाला। 12 अक्तूबर, 1492 में **क्रीस्टोफर कोलम्बस** (CHRISTOPHER COLUMBUS) ने एक उस द्वीप पर अपना पैर रखा जिसे वहाँ के मूल निवासी *गुयानाहानी* (Guanahani) कहते थे। कोलम्बस ने इस द्वीप का नाम *सन सलवाडेार* रखा। आजकल इसे *वाटलिंग* (Watling) द्वीप के नाम से पुकारा जाता है। सन् 1497 में **वास्कोडिगामा** (VASCO DE GAMA) *केप ऑफ गुड होप* की परिक्रमा करके समुद्र के रास्ते से भारत पहुँचा। परन्तु इन महासागरों के बारे में असली ज्ञान सितम्बर, 1513 में **वास्को नूनेज दी बैबाओ** (VASCO NONEZ DE BABBAO) ने प्रस्तुत किया। उन्होंने प्रशान्त महासागर पर ध्यान देते हुए यह स्पष्ट किंया कि भारत और अमरीका की भूमि एक दूसरे के साथ संलग्न नहीं है। सन् 1520 में **फेर्डिनांड मैगेलान** (FERDINAND MAGELLAN) समुद्र के जल संयोगी पथ पर परिक्रमा करते हुए विशाल दक्षिणी समुद्र में पहुंचे, जिसे उन्होंने प्रशान्त महासागर का नाम दिया। उनकी मृत्यु के उपरान्त उनका एक जलपोत सन् 1522 में स्पेन पहुंचा। यह विश्व के सामुद्रिक पथ पर प्रथम सफल अभियान था।''

इसी समय रामू ने प्रश्न पूछा, "समुद्र विज्ञान (ओश्नोग्राफी) क्या है? इसके कौन-कौन से अंग हैं? यह आधुनिक विज्ञान में कैसे परिणत हुआ?''

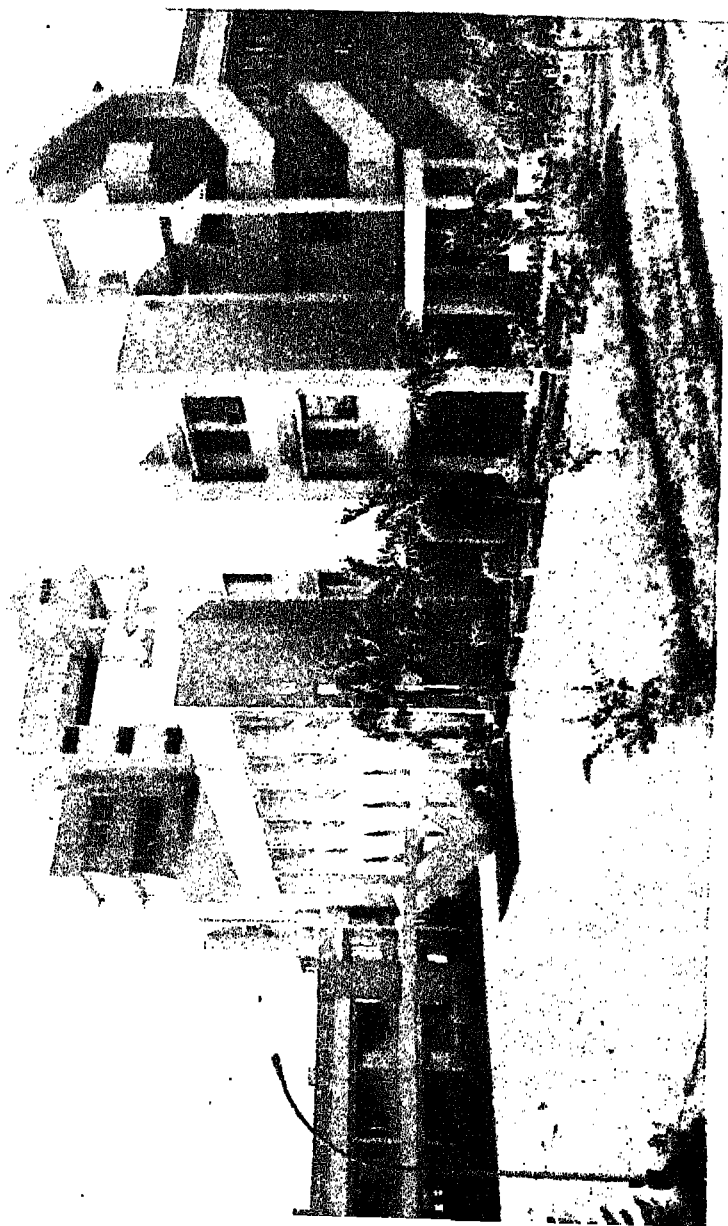
भूगोल के अध्यापक ने समझाते हुए कहा, "ओश्नोग्राफी एक संयुक्त (मिश्र) विज्ञान है। यह विज्ञान की विभिन्न शाखाओं से युक्त है जो समुद्र और महासागर के जीवन और वातावरण से संबंधित है, जैसे कि भौतिक विज्ञान, रासायनिक विज्ञान, प्राकृतिक भूगोल, भूविज्ञान, समुद्री जीवविज्ञान इत्यादि। इस प्रकार महासागर की लहरों, तापमान, लवणता, पानी की सतह और समुद्रतल सामग्री सभी को हम भौतिक और रासायनिक विज्ञान की मदद से जान सकते हैं। समुद्री चार्ट और सामुद्रिक तल का नक्शा, प्राकृतिक भूगोल (Physical Geography) एवं भूविज्ञान (Geology) की

सहायता से तैयार किया जाता है। खगोलीय और मौसम विज्ञान का महासागरों की लहरों और ज्वार भाटा से भी संबंध है। इन सबका अध्ययन जलराशिकी या हाइड्रोग्राफी से संबंधित है। इसके अलावा समुद्री जीव विज्ञान (Marine Biology) है, जो कि समुद्री जानवरों एवं पौधों के बारे में बताता है। समुद्र विज्ञान में प्राणीशास्त्र (Zoology), वनस्पति विज्ञान (Botany) और जीवाणुशास्त्र (Bacteriology) भी शामिल हैं। संक्षेप में हम यह कह सकते हैं कि समुद्री सतह से नीचे सारे संसार का अध्ययन ही समुद्र विज्ञान है। स्पष्ट है कि बार-बार समुद्र में अभियान दल भेजकर ही, समुद्र विज्ञान के बारे में जाना जा सकता है।

प्रथम बार ओश्नोग्राफी का अभियान तब आरम्भ हुआ जब **जेम्स कुक** (JAMES COOK) ने अपने *एंडीवर* (Endeavour) नामक जहाज़ को लेकर सन् 1768 में खोज के लिये अपनी यात्रा आरंभ की। इस अभियान में समुद्र के विभिन्न स्थानों के तापमान का पता लगाया गया और समुद्र की गहराई प्रतिध्वनिक गहराई मापन विधि (Deep Echo Sounding Method) द्वारा मापी गई। इस जहाज़ में एक खगोलज्ञ, दो जीवशास्त्री *(बैंक्स एवं सोलान्डर)* और कुछ कलाकार थे। सन् 1831 में *एच एम एस बिगल* (HMS Beagle) नामक जलपोत में वैज्ञानिक **चार्ल्स डारविन** (CHARLES DARWIN) ने यात्रा की। सन् 1839 में एक अभियान अंटार्कटिक की ओर भी भेजा गया। इस अभियान में *ऐरेलस* (Erelus) और *टेरर* (Terror) नामक दो जहाज़ लगाए गए जिनको **सर जेम्स रौस** (SIR JAMES ROSS) ने परिचालित किया। सन् 1846 में **थामस हक्सले** (THOMAS HUXLEY) ने *एच एम एस रेटेलस्नेक* (HMS Rattlesnake) नामक जहाज़ में यात्रा की। सन् 1860 में **जी सी वैलिक** (G C WALLICH) ने *एच एम एस बुलडाग* (HMS Bulldog) नामक जहाज़ में यात्रा की। उस समय यह विश्वास किया जाता था कि अंटार्कटिक के पास समुद्र में परिस्थितियों के कारण किसी भी प्राणी का अस्तित्व संभव नहीं है। सन् 1868 में पहले *एच एम एस लाइटनिंग* (HMS Lightning) और उसके बाद *एच एम एस परकूपिन* (HMS Porcupine) नामक जहाज़ से गंभीर सागरी निकर्षण (Deep Sea Dredging) द्वारा सभी संबंधित प्रश्नों को समाप्त करने के लिए यात्रा की गई। निकर्षण के शेष होने तक जहाज में

उपस्थित सात वैज्ञानिकों का समय कैसे उत्तेजना से बीता उसका अनुमान नहीं लगाया जा सकता। निकर्षण में काफी समय लग गया। प्रत्येक निकर्षण में मिले जलीय प्राणी और पेड़-पौधे अत्यन्त विचित्र और सुन्दर थे जिससे उन्हें बहुत प्रसन्नता हुई। इससे प्रोत्साहित होकर बहुत से वैज्ञानिक एवं अन्वेषणकारी देश-विदेश से और वैज्ञानिकों को लेकर सामुद्रिक जीव और पौधों के संबंध में अध्ययन के लिए निकल पड़े।

सन् 1872 में ब्रिटिश सरकार ने *एच एम एस चैलेन्जर* (HMS Challenger) नामक जहाज़ को **कैप्टन नैरेस** (CAPT. NARES) के नेतृत्व में भेजा। इस अभियान में कई प्रसिद्ध वैज्ञानिकों को **सर वैविल टॉमसन** (SIR WYVILLE THOMSON) जो कि ऐडिनबरा विश्वविद्यालय में प्राकृतिक इतिहास के प्रोफेसर थे, के साथ भेजा गया। यह जहाज़ तीन साल तक समुद्र में 1,11,040 किलोमीटर (69,000 मील) तक घूमा। पृथ्वी की परिक्रमा करते हुए इस जहाज़ से प्रतिध्वनिक गहराई मापन विधि (Deep Echo Sounding Method) से गहराई मापी गयी तथा समुद्री जल के विभिन्न स्तरों का तापमान लिया गया। समुद्र तली के नमूने भी लिये गए। गहराई में निकर्षण किया गया। जहाज से जाल को बांधकर पानी की सतह और तल के बीच में खींचा गया। सन् 1872 के *चैलेंजर* के अभियान द्वारा काफी समुद्री तत्व एकत्रित किये गए। इनको लेकर विशेषज्ञों ने अन्वेषण किये और महत्वपूर्ण विवरण पेश किये। यही विवरण वर्तमान समुद्र विज्ञान की नींव है। इन विवरणों का **सर जान मुरे** (SIR JOHN MURRAY), जिन्होंने इस अभियान में हिस्सा लिया था, ने संपादन किया। इन विवरणों के आधार पर और भी कई देशों से अभियान आरंभ हुए। चैलेंजर के बाद गहरे समुद्र के कई अभियान जर्मनी ने किये। नार्वे के **प्रोफेसर होर्ट** (HJORT) और इंग्लैण्ड के **सर जान मुरे** ने, जो पहले चैलेंजर में भी यात्रा कर चुके थे, *माइकल सार्स* (Michael Sars) नामक जहाज़ द्वारा फिर से यात्रा आरंभ की। इसके बाद जर्मनी के *मीटिअर* (Meteor) और डेनमार्क के *डाना* (Dana)— इन दो जहाज़ों ने अपना अभियान आरंभ किया। बाद में **कैप्टेन स्कॉट्स** (CAPT. SCOTTS) के नेतृत्व में *डिसकवरी* और उसके बाद *डिसकवरी*-II और *विलियम स्कोर्सबाई* (William Scoresby) जहाज़ ने समुद्र विज्ञान में एक रोचक इतिहास बनाया।

सन् 1901 में समुद्र अन्वेषण के लिये *नेशनल काउँसिल फॉर द एक्सप्लोरेशन ऑफ द सी* (National Council for the Exploration of the Sea) नाम से एक आयोग स्थापित किया गया। इस आयोग को यूरोप के अलग-अलग देशों द्वारा सहायता दी गई। इस आयोग का यह लक्ष्य था कि वह समुद्रों में मत्स्य पालन को बढ़ावा दें। प्रत्येक देश, जो इस आयोग के सदस्य थे, उन्हें अपने कुछ जहाज़ इस काम में लगाने पड़ते थे, जिससे यह जाँच की जा सके कि उन्हें आवंटित समुद्र के किस भाग में क्या समस्याएँ हैं। द्वितीय महायुद्ध के बाद और बहुत से ऐसे संगठनों का निर्माण हुआ। आज़कल *समुद्री अनुसंधान के लिए वैज्ञानिक समिति* (Scientific Committee For Ocean Research) और *अन्तर्राष्ट्रीय सरकारी समुद्री कमीशन* (Inter Governmental Oceanographic Commission) द्वारा और अधिक समुद्री अनुसंधान कार्यों को समन्वयित किया जा रहा है। सन् 1958 में एक अन्तर्राष्ट्रीय सहयोगिता कुछ भिन्न आधारों पर स्थापित की गई। यह वर्ष **अन्तर्राष्ट्रीय भू-भौतिकीय वर्ष** (International Geophysical year) के रूप में प्रसिद्ध है। इस वर्ष कुछ राष्ट्रों ने एक ही समय में समुद्र के भौतिक विषयों का गहराई से निरीक्षण किया। सफलता के परिणामस्वरूप यह निर्णय लिया गया कि हिन्द महासागर के बारे में रासायनिक, भौतिक और जीवविज्ञान का सर्वेक्षण किया जाय, क्योंकि अब तक दूसरे महासागरों की अपेक्षा इसके (हिन्द महासागर) बारे में बहुत कम जानकारी है। सन् 1960-65 के बीच 20 राष्ट्रों के 38 जहाजों ने हिन्द महासागर में समुद्री पर्यटन किया जिसको '**अन्तर्राष्ट्रीय हिन्द महासागर अभियान** (International Indian Ocean Expedition)' के नाम से जाना जाता है। इस प्रयास का एक तत्कालिक लाभ यह हुआ कि अरब सागर के उपकुल में सार्डिन मछलियों का आविष्कार हुआ। हिन्द महासागर के अभियान की सफलता को देखते हुए भारत में समुद्र विज्ञान के महत्व का काफी अनुभव हुआ। इसके फलस्वरूप सन् 1966 में गोवा में **राष्ट्रीय समुद्र विज्ञान संस्थान** (N.I.O.) की स्थापना की गई (चित्र 2)। अभियान के साथ-साथ यह भी अनुभव हुआ कि सभी जगह समुद्र के विषय में प्रयोगशालाएँ भी स्थापित की जानी चाहिएं। इसके बहुत पहले ही सन् 1872 में जर्मनी के **अंटोन डोरन** (ANTON DOHRN) नामक एक जीव वैज्ञानिक ने एक प्रसिद्ध प्रयोगशाला नेपिल्स (Naples) शहर में स्थापित की थी।

चित्र 2 : राष्ट्रीय समुद्र विज्ञान संस्थान (N.I.O.), गोवा।

जर्मन सरकार की ओर से आर्थिक सहायता, संसार की भिन्न-भिन्न वैज्ञानिक समितियों की सहायता, तथा अपनी व्यक्तिगत पूंजी से उन्होंने स्टेजिओन जूलोजिका (Stazione Zoologica) नामक प्रयोगशाला की स्थापना की थी। उसके बाद मोनाको (Monaco) में **प्रिन्स अलबर्ट** (प्रथम) (PRINCE ALBERT-I) ने एक संयुक्त संग्रहालय, प्रयोगशाला और एक्वैरियम या जलजीवशाला की स्थापना की। संग्रहालय में हर प्रकार के सामुद्रिक जीवों का अद्‌भुत संग्रह था। इसमें सभी प्रकार के यंत्र जिनका सामुद्रिक अभियान में प्रयोग हुआ था उनका भी संग्रह था। प्रिन्स अलबर्ट और उसके सहयोगी ने *प्रिन्सेज ऐलिस* (Princess Alice) नामक जहाज़ से यात्रा की थी। इस जहाज की और प्रयोगशाला दोनों की ही एक नकल उनके संग्रहालय में भी रखी हुई है। समुद्री गोताखोरों के जनक माने जाने वाले मेहनती निदेशक प्रो. जे वाइ **कॉस्टियन** (PROF. J.Y. COUSTEAN) की नियुक्ति के बाद इस प्रयोगशाला का एक नया जीवन आरंभ हुआ। इंग्लैण्ड में सबसे बड़ी सामुद्रिक स्टेशन प्लाई माउथ की प्रयोगशाला है। यह प्रयोगशाला विश्व की सभी प्रयोगशालाओं में से एक प्रमुख प्रयोगशाला मानी जाती है। स्काटलैण्ड की सामुद्रिक जीव विज्ञान की एक नई प्रयोगशाला *डँनस्टाफेंज* (Dunstaffnage) में स्थानांतरित हुई है। इंग्लैंण्ड में एक बड़ा सामुद्रिक संगठन है जिसका नाम ***प्राकृतिक पर्यावरण अनुसंधान परिषद्*** (Natural Environmental Research Council) है। इसके अलावा कुछ सामुद्रिक प्रयोगशालाएँ लीवरपुल, वेल्स, लीड्स और न्यूकैसल विश्वविद्यालयों से भी सम्बद्ध हैं। सारे जिले में वरमूले (Wormley) शहर में एक मशहूर राष्ट्रीय समुद्र विज्ञान संस्थान है। नार्वे के असलो शहर में *फ्रिड्टजोफ ननजेन इन्स्टीट्यूट* (Fridtjof Nansen Institute) के अलावा ड्रोबक, ट्रोंडेहम और बरगेन में सामुद्रिक केन्द्र हैं। संयुक्त राष्ट्र अमेरीका में मैसाचेसेटस के वुडसहोल नामक स्थान पर **सामुद्रिक जीव विज्ञान प्रयोगशाला** (Marine Biological Laboratory) दुनियाँ में सबसे बड़ी जीव विज्ञान से संबंधित प्रयोगशाला है। इसके पास ही *वुडसहोल समुद्र विज्ञान संस्थान* (Woodshole Institute of Oceanography) एक विख्यात प्रतिष्ठान है। समुद्र विज्ञान में अमेरिका के ***स्क्रीप्स इंस्टीट्यूट आफ ओसनोग्राफी*** (Scripps Institute of Oceanography) को एक उच्चस्तर के प्रतिष्ठान के रूप में माना जाता है।"

अध्याय 3

समुद्र के जल का संघटन
(COMPOSITION OF SEA WATER)

भूगोल के अध्यापक ने कहा, "रामू समुद्र के बारे में बहुत कुछ जानना आवश्यक है। समुद्र विज्ञान एक ऐसा विज्ञान है जिसमें पहले कोई ज्यादा रुचि नहीं लेता था। यह समझा जाता था कि पृथ्वी के स्थल भाग में जो सम्पदा है, वह मानव जाति के लिये पर्याप्त है। लेकिन आज हम देख रहे हैं कि तेजी से बढ़ती हुई जनसंख्या के लिए स्थल सम्पदा काफी नहीं है इसलिए सागर में छिपी हुई सम्पदा की खोज बहुत ज़रूरी है। आज सारी दुनिया में समुद्र विज्ञान की चर्चा हो रही है। रामू इस विषय में तुम्हारी दिलचस्पी देखकर मैं बहुत ही संतुष्ट हूँ। लेकिन इस विषय में हमारी जानकारी सीमित है। इसलिए मैं तुम्हें एक समुद्र-वैज्ञानिक के पास ले चलता हूँ और उससे परिचय करा देता हूँ। वे तुम्हें इस विषय में और अधिक ज़ानकारी दे सकेंगे।"

रामू को लेकर अध्यापक समुद्र-वैज्ञानिक के पास पहुंचे और उनसे रामू का परिचय कराया। रामू की जिज्ञासा देखकर वैज्ञानिक बहुत ही प्रभावित हुए और उन्होंने रामू की ज्ञान पिपासा संतुष्ट करनी आरम्भ कर दी।

समुद्र वैज्ञानिक ने कहा, "समुद्र के जल को केवल स्वच्छ जल नहीं समझना चाहिए। क्योंकि इसमें नमक तथा खनिज मिले होते हैं। यह जल जीवन्त प्राणी तथा उद्भित इत्यादि का पोषक है। यह पादपप्लवक (Phytoplankton) के विस्तार का सहायक है। यह निश्चित है कि आद्यकालिक समुद्र पृथ्वी पर जीवन के प्रारम्भ होने में एक प्रमुख माध्यम थे।

समुद्री जल का संघटन, विशेषकर पानी में नमक की मात्रा, तापमान, अक्षांश और नदियों से आने वाले पानी के अनुसार बदलता रहता है। कुछ अंत:स्थलीय समुद्र, जैसा कैसपीयन सागर, में समुद्र का पानी नहीं है, और इसीलिए रसायन भी भिन्न है। कुछ अंत:स्थलीय समुद्र के पानी में नमक की मात्रा बहुत अधिक है जैसे अमरीका में ग्रेट साल्ट लेक, जिसमें नमक की मात्रा हजार भाग में 280 भाग है। निकटवर्ती स्थानों की बर्फ पिघलकर स्वच्छ पानी के रूप में आर्कटिक और अंटार्कटिक महासागर में आती हैं इसलिए उनके ऊपरी भाग में नमक की मात्रा सबसे कम होती है।

समस्त प्राकृतिक तत्व समुद्र के जल में वर्तमान हैं। उदाहरण के लिए एक लीटर जल में 35 ग्राम विभिन्न लवणों का मिश्रण है। समुद्र से प्राप्त लवण में 89% क्लोराइड्स, 10% सल्फेट एवं 0.2% कार्बोनेट्स मिले हुए होते हैं। यह जानकर हैरानी होगी कि महासागर और समुद्र में इतना नमक है जो कि सारी पृथ्वी की भूमि को 150 मीटर की ऊँचाई तक ढक सकता है। इसके अलावा, इसमें मैग्नीशियम क्लोराइड, मैग्नीशियम सल्फेट, कैल्शियम कार्बोनेट एवं कैल्शियम पोटेशियम सल्फेट का भी संमिश्रण है। अनेक धातुएँ भी समुद्र के पानी में पाई जाती हैं। सोना लगभग दस लाख में 0.006 भाग में पाया जाता है (अर्थात् 38 से 40 पाउण्ड सोना प्रति दस लाख गैलन समुद्र के पानी में पाया जाता है)। क्या तुम यह सोच सकते हो कि वोल्गा नदी से लगभग 600 टन सोना कैस्पियन सागर को प्रतिवर्ष मिलता है? समुद्र में से सोने के निष्कर्षण की समस्या ने आधुनिक समय में लोगों का ध्यान आकर्षित किया है, जैसा कि तुम जानते हो कि मध्ययुग में अलकेमी विज्ञान (पत्थर को सोने में परिवर्तन करना) से सोना बनाने पर सोच-विचार किया जाता था लेकिन अब तक कोई भी ऐसी विधि नहीं अपनाई गई जिससे समुद्र के पानी से सोना निकालना आर्थिक दृष्टि से लाभदायक होगा।

इस संदर्भ में हम और बताना चाहेंगे कि समुद्री जल में हाइड्रोजन आयन की सांद्रता स्थिर रखनी चाहिए। इस बात को प्रकृति संभालती है। इस सांद्रता का निर्धारण "पी एच" (pH) के द्वारा किया जाता है। उदासीन (Neutral) जल का पी

एच "7" माना जाता है। यदि यह पानी में "7" से कम हो तो पानी अम्लीय (ऐसिडिक) हो जाता है, यदि "7" से अधिक हो तो क्षारीय (एलक्लाइन) होता है। पी एच "7" से जितना ही कम होता है ऐसिडिटी उतनी ही अधिक होगी। समुद्री जल का पी एच "8" होता है। पी एच में 0.5 का परिवर्तन होने से सामुद्रिक जीवन का सर्वनाश हो सकता है। यह अनुमान किया जाता है कि एक प्रतिशत कार्बन, जो कि चट्टानों की पर्तों में बन्द पड़ा है, उसके निकलने से पृथ्वी में सम्पूर्ण परिवर्तन की संभावना है। यदि पी एच 7 से कम हो जाय तो जल के जीव-जन्तुओं से कैल्शियम कंकाल की वृद्धि बन्द हो जायेगी और इससे कैल्शियम कोर्बोनेट का अवक्षेपण नहीं होगा।

कुछ सामुद्रिक पेड़-पौधे पोटेशियम और आयोडीन अपने में समा लेते हैं। इसलिए सामुद्रिक पेड़-पौधे आयोडीन के स्रोत भी हैं। अब हमें स्वच्छ जल और समुद्र के जल में मुख्य अन्तर का पता करना है।

(i) समुद्री जल स्वच्छ जल से अधिक ऊष्मा का चालक (Conductor of Heat) है।

(ii) स्वच्छ जल का घनत्व अधिक से अधिक 4° C में होता है और वह जल हमेशा उसी ताप में समुद्र के नीचे जा सकता है।

(iii) समुद्री जल का सबसे अधिक घनत्व –2.2°C पर होता है जो कि इसका हिमांक है।

(iv) पर्सियन खाड़ी (Persian Gulf) और लाल सागर (Red Sea) के जल का तापमान 35°C तक होता है।

नोभा स्कोसिया के पास समुद्री जल का तापमान –3.3°C तक हो जाता है। पिछले चालीस वर्षों के बीच समुद्री जल से जिन रासायनिक द्रव्यों का निष्कर्षण किया गया वे हैं : ब्रोमीन, मैग्नीशियम और कुछ हद तक पोटेशियम। पोटेशियम की सांद्रता कम होने पर समुद्र से इसका निष्कर्षण आर्थिक रूप से लाभप्रद नहीं माना जाता है। **'खनिज पदार्थों'** शब्दों का मतलब केवल कुछ खनिजों के अस्तित्व ही नहीं है। वास्तव में इनका महत्व इनकी सांद्रता में ही है। इस विषय में मैं तुम्हें एक कहानी सुनाता हूँ। **फ्रिट्ज हबर** (FRITZ HABER) एक विशिष्ट जर्मन रसायनज्ञ थे। उन्हें सन् 1918 में रसायन शास्त्र के क्षेत्र में काम करने पर नोबल पुरस्कार मिला था।

उन्होंने यह विचार दिया कि समुद्र से सोना निकालकर जर्मनी अपने प्रथम विश्वयुद्ध (1914-1918) के ऋण की पूर्ति करे। सन् 1925 में जर्मन अनुसंधान जहाज़ *मीटिअर* को पानी में उतारा गया। अभियान के लिए परियोजना तैयार की गई। दो वर्ष के पश्चात् समुद्र में सोने की मात्रा कम होने से परियोजना को स्थगित कर देना पड़ा। परन्तु इस जहाज(मीटिअर)ने विभिन्न सामुद्रिक तत्वों का अध्ययन किया, साथ ही समुद्री जल का गुणधर्म, समुद्र अधस्तल की प्रकृति इत्यादि का भी पता लगाया। नीचे तालिका नं 1 में महासागरीय खनिज पदार्थ की एक सूची प्रस्तुत की गयी है।

तालिका नं. 1

महासागरीय खनिज पदार्थों की एक सूची

निक्षेप का प्रकार (उपयोग के आधार पर)	*पदार्थ या तत्व*	*भू वैज्ञानिक वितरण*
निर्माण कार्य के लिए	गुटिका, क्वार्ट्स	समुद्रतट और महाद्वीपीय शेल्फ पर
औद्योगिक पदार्थ	फास्फोराइट, गंधक, अरगोनाइट, सिलिका (रेत)	समुद्र तट पर
प्लेसर	लोहा, सोना, प्लेटिनम, टिन, हीरा, दुर्लभ मृदाधातु, जर्कोनियम, टाइटेनियम, क्रोमियम इत्यादि	समुद्रतट तथा उसके नजदीक उथले जल में
हाईड्रोकार्बन	पेट्रोलियम (तिल तथा गैस) कोयला	मुख्यत: निष्क्रिय महाद्वीपीय सीमा तक
बहुधात्विक ऊष्णजलीय सल्फाइड	लोहा, तांबा, मैंगनीज, सीसा, जिंक, चांदी, इत्यादि	विभंग क्षेत्र@ और विस्तारक केन्द्र*
बहुधात्विक पिंड और पर्पटी	मैंगनीज, लोहा, कोबाल्ट, निकेल, तांबा, टाइटेनियम, मोलिब्डेनम इत्यादि	गंभीर समुद्रतल में (4000 मी. से भी नीचे)
समुद्रजल	ब्रोमीन, मैग्नीशियम, लवण, यूरेनियम, पोटेशियम, जिप्सम, इत्यादि	सार्वत्रिक लेकिन पानी का खारापन परिवर्तित होता है।

@ FRACTURE ZONE ,
* SPREADING CENTRE

अब व्यवसायिक रूप में कई जरूरी द्रव्य, जैसे पोटेशियम, आयोडिन, मैग्नीशियम एवं कैल्शियम की खोज का प्रयत्न किया जा रहा है। हाल ही में जापान ने समुद्र के जल से यूरेनियम निकालने की पद्धति आरंभ की है। यह निश्चित है कि इन क्षेत्रों में अनुसंधान कार्यों को बढ़ावा दिया जायेगा और सन् 2020 तक बहुत अधिक संख्या में तत्वों को व्यावसायिक रूप से निकाला जाना शुरू हो जायेगा।

तालिका नं. 2

नीचे समुद्री जल में विविध तत्वों के सांद्रण की एक सूची प्रस्तुत की गयी है–
(10 हजार लाख या 1 बिलियन भाग में)

(क) 1000 भाग या उससे ज्यादा या 1 पीपीएम से अधिक

तत्व	*सांद्रण*	*तत्व*	*सांद्रण*
ऑक्सीजन	857,000,000	पोटेशियम	380,000
हाइड्रोजन	108,000,000	ब्रोमीन	65,000
क्लोरीन	19,000,000	कार्बन	28,000
सोडियम	10,500,000	स्ट्रोंशियम	8,000
मैग्नीशियम	1,350,000	बोरॉन	4,600
सल्फर	890,000	सिलिकन	3,000
कैल्शियम	400,000	फ्लुओरीन	1,300

(ख) 1 भाग या उससे ज्यादा लेकिन 1000 भाग से कम (अर्थात् 1 पीपीबी से 1 पीपीएम तक)

आर्गन	600	एल्युमिनियम	10
नाइट्रोजन	500	मॉलिब्डेनम	10
लीथियम	170	ताँबा	3
रूबिडियम	120	आर्सेनिक	3
फास्फोरस	70	यूरेनियम	3
आयोडीन	60	निकल	2
बेरियम	30	वैनेडियम	2
इंडियम	20	मैंगनीज	2
जिंक	10	टाइटेनियम	1
लोहा	10		

(ग) हर 1 बिलियन भाग में 1 भाग से भी कम (अर्थात् 1 पी पी बी से कम)

तत्व	*सांद्रण*	*तत्व*	*सांद्रण*
टिन	0.8	सीसा	0.03
सीजियम	0.5	मर्करी	0.03
ऐंटिमनी	0.5	गैलियम	0.03
सिलेनियम	0.4	बिस्मथ	0.02
इट्रियम	0.3	नायोबियम	0.01
कैडमियम	0.1	लैथेनम	0.01
टंगस्टेन	0.1	थैलियम	0.01
कोबाल्ट	0.1	सीरियम	0.005
जर्मेनियम	0.06	सोना	0.004
क्रोमियम	0.05	दुर्लभ मृदा धातु	0.003 – 0.0005
थोरियम	0.05	प्रोटोऐक्टिनियम	2×10^{-6}
चांदी	0.04	रेडियम	1×10^{-7}
स्कैंडियम	0.04		

अध्याय 4

समुद्र के जीवित प्राणी

(MARINE LIVING ANIMALS)

वैज्ञानिक ने रामू को समझाया– "पृथ्वी की आयु लगभग चार सौ साठ करोड़ साल है (4.6 बिलियन वर्ष)। सबसे प्राचीन मानी हुई पथरीली चट्टान, चार सौ करोड़ साल पुरानी है। इससे पता चलता है कि लगभग साठ करोड़ साल का पृथ्वी का इतिहास अज्ञात है। यह विश्वास किया जाता है कि आज वायुमंडल एवं जलमंडल की शुरुआत पृथ्वी की भू-पटी चट्टानों के गलने से हुरू हुई। चट्टानों के इस तरह गलने से उसमें से आबंध्य गैसें बाहर निकल आयीं।

यह पथरीले पहाड़ों को गला देने वाली ऊष्मा कहाँ से आती है? इस ऊष्मा का स्रोत या तो रेडियोसक्रियताजन्य गरमी है या यह ज्वारीय घर्षण होती है अथवा पृथ्वी की गुरुत्वाकर्षण शक्ति से (Gravitational Energy) होती है। यह जानना महत्वपूर्ण होगा कि पृथ्वी के आरम्भ में ऑक्सीजन गैस रासायनिक तलछट में पायी जाती थी एवं मुक्त ऑक्सीजन चारों ओर वातावरण में नहीं थी। यह बाद में समुद्र से ही निकली। जलमण्डल एवं वायुमंडल 3.5-3.6 इअन में आरंभ हुआ। एक इअन 100 करोड़ साल के बराबर होता है। पृथ्वी पर जीवन इसी के साथ-साथ आरम्भ हुआ। सूक्ष्म-जीवाश्म इअन 3.2 की आयु के पुराने पहाड़ों में पाये जाते हैं।"

रामू ने पूछा, "पृथ्वी में जीवन का प्रारम्भ कैसे हुआ?"

वैज्ञानिक ने उत्तर दिया,"आज से लगभग 100 करोड़ साल पहले प्रथम जीवित प्राणी का समुद्र में जन्म हुआ। कोई भी इसके बारे में निश्चित रूप से नहीं जानता कि निर्जीव वस्तुएँ कैसे सजीव प्राणियों में बदल गई।

संभवतः प्रथम जीवित प्राणी आज की वायरस (Virus) कहलाई जाने वाली वस्तु से मिलता-जुलता था। इसमें जीवित पोषक शक्ति थी साथ ही पानी में उपस्थित सरल पदार्थों को अपनी ही तरह जटिल पदार्थों में परिवर्तित करने की भी शक्ति होती थी। ऐसे प्रथम सजीव पदार्थ भी दिन प्रतिदिन जटिल होते गये। इसमें एक हरा यौगिक पदार्थ भी था जिसको **क्लोरोफ़िल** (Chlorophyll) के नाम से जाना जाता है। यह समुद्री जल से पानी और कार्बन–डाई–ऑक्साइड गैस ग्रहण करके सूर्य की किरणों से इनको खाद्य में परिवर्तित करता था तथा ऑक्सीजन गैस छोड़ता था। इसी को वास्तव में सबसे पहला एक कोशिका वाला पौधा बताया जाता है। करोड़ों वर्षों के बीतते–बीतते सजीव प्राणी धीरे–धीरे अपना भोजन बनाने की शक्ति खो बैठे परन्तु वे भोजन खाकर जिन्दा रहने की क्षमता को अपनाये रहे और यही सबसे पहले सबसे छोटे जीव थे जिन्होंने पृथ्वी पर जन्म लिया। आज दस लाख से भी अधिक प्रकार के पौधे तथा जीव-जन्तु पृथ्वी पर विद्यमान हैं। अब यह स्पष्ट नहीं है कि उनकी उत्पत्ति एक प्रकार के अथवा एक से ज्यादा प्रकार के प्राणियों से हुई। परन्तु एक कोशिका वाले जीवों (जो अभी विद्यमान हैं) के इतिहास का अध्ययन करके कुछ सुराग मिल सकता है।

हर कोशिका का भीतरी भाग एक जैसा नहीं होता। प्रत्येक के अन्दर एक प्रकार का आन्तरिक क्रोड/केन्द्रक पाया जाता है। इस केन्द्रक के अन्दर पदार्थ की उपस्थिति माइक्रोस्कोप द्वारा देखी जा सकती है जिन्हें क्रोमोजोन कहते हैं। जब यह कोशिका वृद्धि की एक निश्चित सीमा तक पहुँच जाती है तब ये क्रोमोजोन कोशिका के बाहर जाकर विभाजित हो जाते हैं। उसके बाद केन्द्रक अपने आप दो भागों में विभक्त हो जाता है। तब प्रत्येक केन्द्रक क्रोमोजोन का एक सेट पाया जाता है। आखिर में सम्पूर्ण कोशिका दो संतति कोशिकाएँ बनाती है। दोनों संतति कोशिकाएँ यदि स्वस्थ हों तो उनकी वृद्धि होती रहती है तथा वे मूलकोष की तरह हो जाती हैं।

कभी कभी ये क्रोमोजोन बराबर भागों में विभाजित नहीं होते अथवा उनकी आकृति एवं संघटन में थोड़ा सा परिवर्तन हो जाता है। ऐसा होने पर दोनों संतति कोशिकाएँ एक दूसरे से भिन्न होती हैं। जब एक ही प्रकार के जीव–जन्तुओं के समूह

का परिवर्तन आरंभ होता है तो यह संभव है कि उसमें से कुछ जीव जीवन के संघर्ष में जीवित रह जाते हैं और उनमें वृद्धि और विभाजन की अधिक संभावना होती है। आकृति में उत्पन्न हुई विभिन्नता यदि उन्नत हुई तो अगली पीढ़ी तक पहुँचती है।

विकास के प्रारम्भ में कुछ कोशिकाएँ टूटने पर अलग-अलग नहीं हुई हैं। बल्कि उन्होंने एक दूसरे से बंधी हुई एक कॉलोनी बनायी, किन्तु कॉलोनी के बीच प्रत्येक कोशिका ने स्वयं अपना पोषण किया मानो वे अकेली ही हों।

एक ही प्रकार की कोशिका की कॉलोनी में से कभी-कभी अधिक जटिल कॉलोनी की उत्पत्ति होती है और उसमें विभिन्न प्रकार की कोशिकाएँ विशेष रूप से आरंभ होती हैं। प्राचीन पत्थरों के जीवाश्म (Fossil) से ज्ञात होता है कि जीव-जन्तु जिसे हम स्पंज कहते हैं वह 50 करोड़ (5000 लाख) वर्ष पहले भी पाये जाते थे। एक स्पंज में कुछ प्रकार की कोशिकाएँ मजबूत कंकाल बनाती हैं जो कॉलोनी को ढक देता है तथा कई कोशिकाएँ धारा की सृष्टि करती हैं। यही धाराएँ भोजन के अंश को दैहिक कोशिकाओं में ले जाती हैं। कुछ कोशिकाएँ वंश वृद्धि के प्रयोग में आती हैं।

समुद्र के साधारण जीव-जन्तुओं में से कृमि के बारे में उल्लेख किया जा सकता है। कृमि में उन्नत रक्त वाहिकाएँ, मुंह, पाचन नली, स्नायु इत्यादि पाए जाते हैं। प्रारम्भ में कुछ कृमि खंडों में विभाजित हुए। हर खंड एक जैसे लगते थे किन्तु बाद में उनकी आकृति और कार्य दोनों में ही भिन्नता आ गयी। इस विकास के कारण कृमि जटिल रूप में कार्य कर सकते हैं। इस प्रकार नाल कृमि (ट्यूब वर्म) अपने शरीर के लचीले पदार्थ तथा रेत का प्रयोग करके अपने चारों ओर रहने के लिए एक लम्बी नली बना लेते हैं। ऊपर से सूंड़ निकालकर वे भोजन का शिकार करते हैं। जब कोई शत्रु उन पर आक्रमण करता है तो वे सम्पूर्ण रूप से नली के अन्दर चले जाते हैं। शेष भाग को अंदर से डाट लगाकर सील कर लेते हैं।

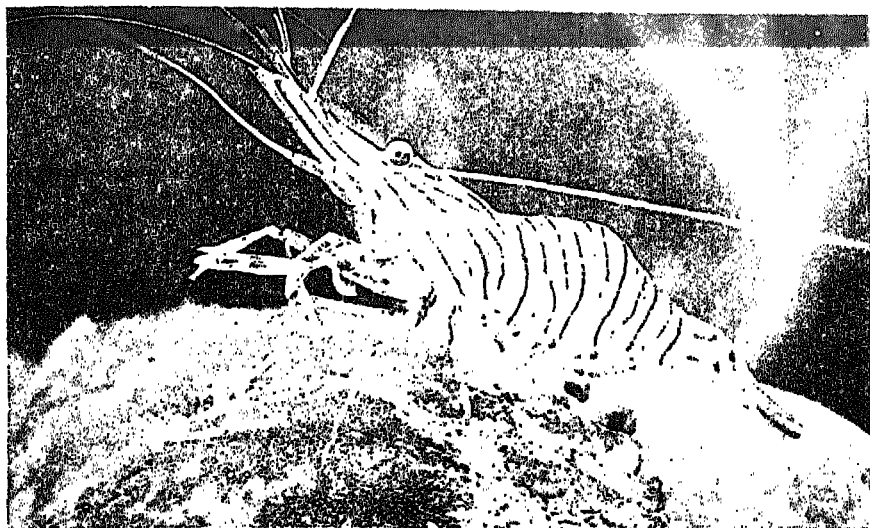
समुद्र के प्रारंभिक जीव-जन्तु मुलायम शरीर के होते थे और नरम शरीर वाले ये जीव-जन्तु जीवाश्म (Fossil) नहीं छोड़ते थे। परिणामस्वरूप हम उनके आयतन, आकृति तथा ढाँचे के बारे में कुछ नहीं जान सके। 50 करोड़ वर्ष पहले मजबूत खोल वाले जन्तुओं का जन्म हुआ। उस युग के पर्वतों के जीवाश्म से यह पता चलता

है कि दो प्रकार के जन्तु समुद्र के पानी में मुख्य रूप से विराजमान थे। वे ***मौलस्क*** (Mollusc) तथा ***आर्थ्रोपोडा*** (Arthropoda) कहलाए। वे कृमि वंश के थे।

कई मोलस्क आज भी मिलते हैं। इनमें ***सीप*** (Oyster), ***मसल*** (Mussel), ***कांकल*** (Cockles), ***कंगूरा*** (Scallops), ***शंबुक*** (Snail) और ***ऑक्टोपस*** (Octopus) आदि जो जेट की भाँति तैरते हैं भी शामिल हैं। मोलस्क अपने खून की शिराएँ तथा हृदय अपने आप ही तैयार करता है। यह क्लोम (Gills) द्वारा सामुद्रिक जल से ऑक्सीजन ग्रहण करता है। इसमें एक सुविकसित स्नायु भी है। धीरे-धीरे कोई एक जाति (स्पीशीज) ताजे जल और पृथ्वी में आ गई। रामू, शायद तुम जानते हो, आजकल कोई भी सीप या शंबुक नमी के बिना अधिक समय तक जीवित नहीं रह सकती।

विशाल सामुद्रिक मछली ***स्क्विड*** सबसे बड़ा जीवित मोलस्क है। यह आकृति में 5 या 6 मीटर लम्बी है। तुम्हें यह जानकर आश्चर्य होगा कि कोई-कोई जीव जो समुद्र की अन्धकारयुक्त गहराई में रहते हैं वे केवल विशाल ही नहीं होते हैं बल्कि समस्त जीव जन्तुओं से तेज होते हैं। उनकी रीढ़ की हड्डी भी नहीं होती।

आर्थ्रोपोडा या ***जुड़ी टांगों*** वाले जानवरों के समूह की संख्या आजकल समस्त जानवरों की संख्या से अधिक है। इनमें समुद्री जल तथा स्वच्छ जल में रहने वाली जैसे ***झींगा मछली*** (लॉब्सटार) (चित्र नं. 3), ***केकड़ा*** (क्रेब) (चित्र नं. 4), ***चिंगट*** (शृम्प), **खंडावर** (बार्नेकल) इत्यादि के अलावा **मकड़ी, बिच्छू** तथा अन्य **कीड़े-मकोड़े** भी शामिल हैं।

कठोर पीठ वाले जानवर 40 करोड़ वर्ष या उससे भी पहले समुद्र में उत्पन्न हुए। समय के अनुसार उनकी वृद्धि काफी जटिल रूप से हुई। दूसरे जानवर ग्रेसल उपास्थि या कार्टिलेज के थे जिनमें जबड़े और कंकाल पाए गए हैं। सबसे पहली मत्स्य जो उपास्थि (कार्टिलेज) से हड्डी में परिवर्तित हुई ऐसी मत्स्य 30 करोड़ वर्ष पहले पायी गई है। जैसा कि तुम जानते हो कि हड्डी वाली मछलियाँ और उनके पूर्वज कार्टिलेज सम्बन्धी मछलियाँ जैसे **शार्क, स्केट** तथा रे मछलियाँ समुद्री प्राणियों में सबसे प्रभावशाली हैं। आज 20000 से अधिक प्रकार की मछलियाँ जीवित हैं।

चित्र 3 : झींगा मछली

चित्र 4 : केकड़ा

उष्णकटिबंधीय ताजा जल के जन्तुओं की आकृति 0.6 से.मी. से लेकर विशाल ह्वेल, शार्क मछलियाँ छोटे बड़े आकार की होती हैं। ह्वेल तथा शार्क की लम्बाई 15 मीटर तक है तथा वजन कई टन। महासागर की सबसे अधिक गहराई में ऐसी मछलियाँ है जिनके सिर, जबड़े, और डरावने दाँत होते हैं। उष्णकटिबंधीय क्षेत्र में उड़ने वाली मछलियाँ भी देखी गयी हैं। जब किसी शत्रु द्वारा उनका पीछा किया जाता है तब वे सौ मीटर की दूरी तक अपने चौड़े पंखों द्वारा जल से निकल कर उड़ती हैं। ये चौड़े पंख वक्ष की रक्षा करने वाले उन्नत पंख होते हैं। कुछ मछलियाँ जहरीली, काटों वाली भी होती हैं तथा कुछ मछलियों के तलवार की तरह थूथन होते हैं। कुछ मछलियाँ अपनी आकृति को बढ़ाकर दुगुना कर लेती हैं चपटी मछलियाँ जैसे **रे** तथा **हैलीबट**। कुछ मछलियाँ शरीर को लम्बा करने वाली होती हैं जैसे **पाइक्स** तथा ईल।

यह रोचक बात है कि रीढ़ की हड्डी वाली मछलियाँ प्राचीनकाल की ***लैटिमेरिया*** (Latimeria) मछलियों की वंशज हैं। लैटिमेरिया जिसका प्रत्येक अंग मछली के पखों की तरह होता है, प्रथम जलस्थली (उभयचरी) थीं। यह बहुत समय तक मेंढक की भाँति पानी में रहती थीं। समय के अनुसार कुछ जलस्थली (उभयचरी) जल से स्वाधीन रहने लगीं तब उनका विकास बहुत तेजी से हुआ। 20 करोड़ वर्ष पहले ***सरीसृप*** (Reptiles) तथा विशाल ***डाइनोसॉर*** (Dinosaurs) का प्रारंभ हुआ। कुछ सरीसृपों ने समुद्र में वापस जाकर अपना विकास आरंभ किया उसके बाद **विशाल कूर्म** (Turtle) की उत्पत्ति हुई। बहुत से सामुद्रिक सरीसृप आज जीवित नहीं हैं। सामुद्रिक साँप उथले जल में पाये जाते हैं। खुले समुद्र में अब केवल विशाल कवचित कूर्म ही पाये जाते हैं।''

रामू ने अब स्तनधारी सामुद्रिक जन्तु के बारे में जानना चाहा–''स्तनधारी कैसे सामुद्रिक जन्तुओं में आए?''

वैज्ञानिक ने समझाया कि ***ह्वेल, शिशुक*** (Porpoise), ***डालफिन*** (Dolphin), ***तिमिगणीय*** (Cetaceans) मुख्य स्तनधारी सामुद्रिक जीव हैं। अब हमें सामुद्रिक स्तनधारी जन्तुओं के विकास के बारे में जानना है। स्तनधारी जन्तुओं की उत्पत्ति

स्तनधारी जाति सरीसृप से होती है जो सरीसृप 28 करोड़ वर्ष पहले प्रकट हुए थे। आखिरी ट्राइऐसिक (Triassic) युग तथा प्रारंभिक ज्यूरैसिक (Jurassic) युग के समय लगभग 19 करोड़ वर्ष पहले प्रथम स्तनधारी जन्तु का आविर्भाव हुआ। क्रिटेशस (Cretaceous) के समय अर्थात् लगभग 13.6 करोड़ से 6.5 करोड़ वर्ष पहले स्तनधारी का विकास हुआ जो बाद में विभिन्न आकृतियों में बदल गये जिन्हें आज हम देखते हैं।

जैसे-जैसे धरती पर रहने वालों की संख्या में वृद्धि होती गई, कुशल स्तनधारियों ने सरीसृपों को खदेड़ दिया और समुद्र को अपना घर बनाया। इन स्तनधारियों में शील मछलियों ने अपना संबंध धरती के साथ रखा। परन्तु ह्वेल और उनसे संबंधित जन्तुओं ने स्थल से अपना संबंध पूरी तरह से समाप्त कर दिया। अन्य समस्त स्तनधारियों में विशेष रूप से ह्वेल का शरीर बालरहित होता है। कुछ विशेष जाति की मछलियों में थूथन और मुंह के आसपास तथा चिबुक पर बाल होते हैं। ये अपने शरीर को गर्म कैसे रखते हैं? छोटी मछलियों में एक चरबी का स्तर होता है जिसकी मोटाई अधिक से अधिक 5 सें.मी. होती है जबकि बड़ी ह्वेल में चरबी का यह स्तर 30 सेंटीमीटर मोटा पाया जाता है। ह्वेल के स्तन गाय के जैसे होते हैं। परन्तु ये शरीर की सतह को छोड़कर खाँचे में होते हैं।''

रामू ने वैज्ञानिक से कहा, "मुझे विभिन्न ह्वेलों के विषय में भी कुछ ज्ञान दीजिए।''

वैज्ञानिक ने कहा, "ह्वेल की कई जातियाँ होती हैं। दन्तवर्गीय ह्वेल विशाल आकार से लेकर छोटे से छोटे आकार में पायी जाती हैं। दन्तवर्गीय में स्पर्म ह्वेल वजन में 50 से 60 टन तक होती है। दूसरी दन्तयुक्त ह्वेल में पिग्मी स्पर्म ह्वेल, बोतल की तरह नाक वाली ह्वेल, कीलर ह्वेल, शिशुक तथा डालफिन शामिल हैं। सबसे छोटी डालफिन वयस्क अवस्था में चाहे 120 से.मी. लम्बी ही हो पर इसका वजन लगभग 145.2 किलोग्राम तक होता है।

ह्वेलबोन ह्वेल (Whalebone Whale) सामान्य आकार से लेकर विशाल आकार तक की होती है। पिग्मी राइट ह्वेल– ***कैपरिया मार्जीनाटा*** (Caperia Marginata)

सबसे छोटी आकृति की ह्वेल है जिसकी लम्बाई 6 मीटर होती है। सबसे विशाल ह्वेल– *ब्ल्यू ह्वेल* (Blue Whale) है। इसकी लम्बाई 30 मीटर से भी ज्यादा होती है तथा वजन में यह कम से कम 160 टन होती है। यह पृथ्वी तथा समुद्र के सभी जन्तुओं में सबसे विशाल है। यहाँ तक कि विशाल डाइनोसॉर का वजन संभवत: 80 टन से अधिक नहीं रहा होगा।''

रामू ने वैज्ञानिक से पूछा, "यदि ह्वेल इतनी विशाल आकृति की है तो वह अपने शरीर को पानी में कैसे रख पाती है?''

वैज्ञानिक ने उत्तर दिया, "विशाल आकृति की ह्वेल को पानी ही सहारा देता है। यदि उसको तट पर लाया जाय तो उसके वजन से उसके बेसहारे शरीर के अस्थि-पंजर टूट सकते हैं, फेफड़े फूट सकते हैं तथा अन्य आन्तरिक इन्द्रियों के नष्ट होने की संभावना रहती है।''

"मुझे ह्वेल के बारे में और कुछ बताइये,'' रामू ने अनुरोध किया।

"ह्वेल का शरीर गोल लम्बाकार (सिगार की तरह) होता है। ह्वेल की हड्डीविहीन पूंछ प्रधान नोदक अंग है। ह्वेल अपनी पूंछ को ऊपर नीचे करते हुए सम्पूर्ण पानी में घुमाती है। दूसरी मछलियों की तरह अपनी पूंछ को क्षैतिज ढंग पर एक तरफ से दूसरी तरफ नहीं करती। ह्वेल का अग्रपाद नोदन में हाथ के समान सहायता करता है, एवं शरीर को स्थिति में रखकर दिशा बदलने में सहायता देता है। ह्वेल की पीठ के ऊपर 1.8 मीटर तक लम्बा पृष्ठ पंख होता है। यह अधिकतर ***कीलर ह्वेल*** में ही पाया जाता है।''

"ह्वेल कैसे सुनती है?'' रामू ने टोकते हुए पूछा।

"इनके बाहर की ओर कोई कान नहीं है। एक बहुत छोटा सा कान का रास्ता शरीर की सतह से अन्दर की ओर जाता है'', वैज्ञानिक ने उत्तर दिया। वैज्ञानिक आगे कहता गया, "ह्वेल के संबंध में और कई विशेष बातें हैं जो तुम्हें जाननी चाहिए। ह्वेल की आँखें शरीर की अपेक्षा बहुत छोटी होती हैं। इनका सांस छिद्र सिर के ऊपर होता है जिससे वे ऊपर की ओर तैरते हुए सांस ले सकें। ह्वेल के एक जोड़ा स्तन होते हैं। परन्तु जैसा मैंने तुम्हें बताया कि ये शरीर की सतह पर

न होकर नीचे खाँचे में अन्दर की ओर होते हैं। जब शिशु ह्वेल दूध पीती है तो ये बाहर की ओर निकल आते हैं। ह्वेल सबसे तेज चलने वाला सामुद्रिक जानवर है। डालफिन 25-32 कि.मी. प्रति घंटे की रफ्तार से अपनी यात्रा करती है। आमतौर से **ब्ल्यू ह्वेल** प्रति घंटे 11 कि.मी. की गति से चलती है किन्तु जरूरत पड़ने पर ब्ल्यू ह्वेल 27 कि.मी. प्रति घंटे की रफ्तार से अपनी गति को और बढ़ा सकती है और इस प्रकार वह 40 किलोमीटर प्रति घंटे की गति से दौड़ सकने में सक्षम हो सकती है। हमें यह भी जान लेना चाहिए कि ह्वेल पानी की सतह पर सोती है और आवश्यकता पड़ने पर पूंछ के कुछ झटकों से ही उसका सिर ऊपर की ओर आ जाता है जिससे वह सांस ले सके। यद्यपि ह्वेल अपनी आँखें बन्द रख सकती हैं परन्तु वे जब सोती हैं तब भी अपनी आँखें 15-30 सेकंड से अधिक बन्द नहीं रखतीं।''

"मुझे अब बताइये,'' रामू ने अनुरोध किया, "कितनी देर तक ह्वेल पानी के नीचे रह सकती है?''

वैज्ञानिक ने उत्तर दिया, "**फिन ह्वेल** पानी में 30 मिनट के लिए, **ब्ल्यू ह्वेल** 50 मिनट के लिए, **स्पर्म ह्वेल** 75 मिनट के लिए, **ग्रीनलैण्ड राइट ह्वेल** 80 मिनट के लिए तथा कई प्रकार की ह्वेल 120 मिनट तक पानी की सतह के नीचे रह सकती हैं। वे विभिन्न गहराइयों में गोते लगा सकती हैं। **डालफिन** थोड़ी ही गहराई तक नीचे जाती हैं, जबकि **फिन ह्वेल** 84 मीटर से 350 मीटर तक नीचे जा सकती हैं। प्राप्त रिपोर्टों के अनुसार **स्पर्म ह्वेल** 1000 मीटर से भी अधिक गहराई में जा सकती हैं।

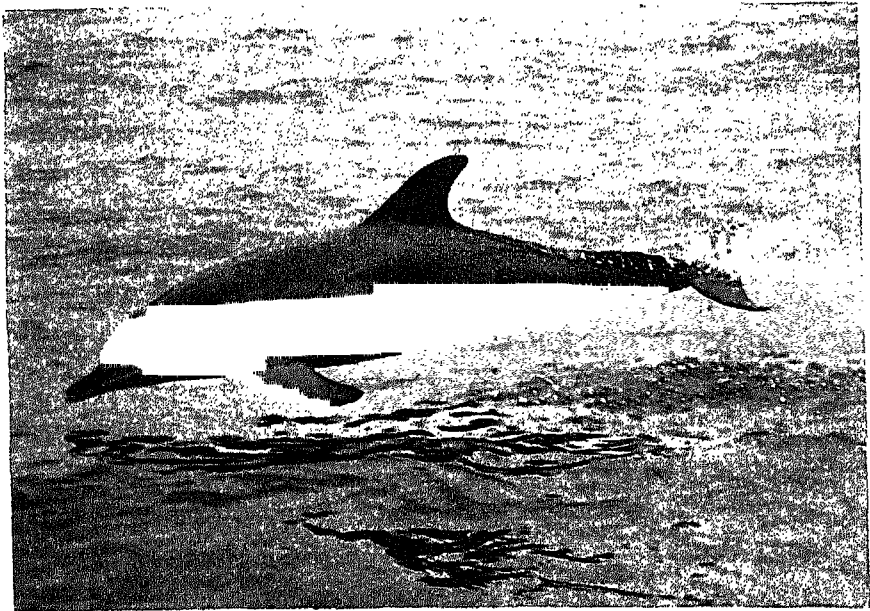
ह्वेल शिकारी द्वारा आक्रमण होने पर, 400 मीटर की गहराई तक चली जाती हैं। ह्वेल के हृदय की गति बहुत धीमी होती है। **ब्ल्यू ह्वेल** के हृदय की लम्बाई 2 मीटर के करीब होती है और उसके हृदय का वजन 0.5 टन होता है। **स्पर्म ह्वेल** की श्रवण शक्ति बहुत तीव्र होती है। जब ह्वेल-शिकारी 16 किलोमीटर की दूरी पर होते हैं तभी ह्वेल को आक्रमणकारियों का आभास हो जाता है। **स्पर्म ह्वेल** सीटी तथा विभिन्न प्रकार के स्वर उत्पन्न करती है। **स्पर्म ह्वेल** का शिकार तेल के

लिए किया जाता है। यह तेल पहले ईंधन, मोमबत्ती तैयार करने एवं मलहम तथा प्रसाधन सामग्री तैयार करने के लिए प्रयोग में लाया जाता था।

अब मुझे ह्वेल के भोजन के विषय में भी कुछ बताने दो। **दन्तवर्गीय ह्वेल** अनेक प्रकार की मछलियों का आहार करती हैं। कुछ विशेष प्रकार की डालफिन के 260 दाँत होते हैं। इतने दाँत रखना एक स्तनधारी जीव के लिए रिकार्ड है। अन्य दन्तवर्गीय ह्वेल के सामान्य दाँत होते हैं। कुछ विशेष ह्वेलबोन ह्वेलों को छोड़कर, इनमें ज्यादातर के दाँत नहीं होते। बल्कि जबड़े के स्थान पर अवशिष्ट ढांचा होता है।

अब हम तुम्हें बहुत रोचक बात बतायेंगे। हाथी के अतिरिक्त ह्वेल ही एक ऐसा जानवर है, जिसका मस्तिष्क आदमी के मस्तिष्क से बड़ा होता है। उसके मस्तिष्क का वजन अनुपात में शरीर के वजन से बहुत कम है। शिशुक में यह अनुपात 0.8% तथा स्पर्म ह्वेल में केवल 0.007% होता है। कई छोटे प्रकार के ***सिटेसियस*** (तिभिगणीय) बहुत तीव्र बुद्धि के होते हैं और कभी-कभी तो वे कुत्ते से भी अधिक होशियार होते हैं। सूंघने की शक्ति ह्वेलबोन ह्वेल में कम तथा दन्तवर्गीय ह्वेल में बिल्कुल नहीं होती है लेकिन उनकी श्रवण शक्ति बहुत तीव्र होती है।''

वैज्ञानिक ने रामू से कहा, "अब मैं तुम्हें एक और बहुत दिलचस्प बात बताऊँगा। कई प्रकार की दन्तवर्गीय ह्वेल प्रतिध्वनि से अपने भोजन के स्थान की जानकारी कर लेती हैं। ह्वेल से निकला हुआ यह शब्द अधिकतर 100 किलोहर्टस से 120 किलोहर्टस (Kilohertz) के बीच होता है। डालफिन में 0.0003 सेकण्ड तथा स्पर्म ह्वेल में 0.024 सेकेण्ड में ये शब्द कई सौ बार होता है। यह ज्ञात है कि ये जानवर अपने मस्तिष्क को इधर-उधर हिलाते हुए इस प्रकार जाते हैं जैसे कि वे रोशनी से खेल रहे हों। जाते हुए इनके शब्दों की आवाज जैट इंजन की भाँति होती है।

जैसा कि पहले कहा गया है कि ***सिटेसियस*** (तिभिगणीय) बहुत तीव्र बुद्धि की होती है। इसी वर्ग की डालफिन को इस प्रकार सिखाया जाता है कि वह पानी के नीचे से भी वस्तुओं को खोज लेती हैं। डालफिन आँख बन्द करके भी पानी के थोड़ा ऊपर रखे हुए डंडे पर उछल सकती हैं (चित्र-5) जो यह प्रतिध्वनि के आधार पर करती है। दन्तवर्गीय ह्वेल भी ध्वनि द्वारा संचार का आदान-प्रदान करती है। यह ध्वनि सीटी

चित्र 5 : डालफिन

की जैसी होती है। इसकी अधिकतर ध्वनि का समय 0.05 सेकेण्ड का होता है। इस आवाज़ की आवृंति 4 से 20 क़िलोहर्टज होती है और शायद यह कंठनली से निकलती है।

सबसे प्रिय तथा प्रसिद्ध दन्तवर्गीय ह्वेल डालफिन ह्वेल है। इनको आमतौर से समुद्री पार्क तथा डालफिनमेरिया में रखा जाता है। डालफिन 35 किलोमीटर प्रति घंटे की रफ्तार से तैर सकती है। जैसा कि मैंने बताया कि डालफिन उछलने में बहुत कुशल है और वह तीव्र बुद्धि की होती है। रामू तुम्हें यह जानकर रुचिकर लगेगा कि सम्भवत: डालफिन समस्त जलीय स्तनधारियों में सबसे अधिक बुद्धिमान है। यदि इनको उचित प्रकार के खेलों का प्रशिक्षण दिया जाय तो ये पानी की सतह से ऊपर उछल सकती है, ऊपर रखी वस्तुओं को पकड़ सकती हैं, पानी में पोलो खेल सकती हैं तथा अपना सिर ऊपर करके खड़ी हो सकती हैं। मैरिन पार्क में डालफिन को 6 मीटर की ऊँचाई तक उछलते हुए देखा गया है। डालफिन को रंगों की

पहचान की शिक्षा दी जा सकती है। अब, मैं तुम्हें एक रोचक कहानी बताऊँगा। किसी मैरिन पार्क में डालफिन को भोजन के लिए एक निश्चित रंग के बटन को दबाना सिखाया गया। उसके पश्चात् विभिन्न रंग के बटन ऊपर नीचे करके बिखरे क्रम में उसके सामने रखे गए। देखने में आया कि डालफिन ने ठीक रंग का ही बटन दबाया जिससे भेंट स्वरूप उसको भोजन प्राप्त हुआ। ऐसा कहा जाता है कि डालफिन कभी-कभी डूबते हुए आदमी को भी बचा लेती है। टूटकर डूबते हुए जहाज़ के यात्रियों को डालफिन ने तैरकर तट पर पहुँचाने में सहायता भी की है। फ्लोरिडा में एक गृहणी शाम के समय तैरते हुए अचानक डूबने लगी। इसी बीच उसे महसूस हुआ कि कोई उसे धक्का देकर तट पर पहुँचा रहा है। बाद में उस गृहणी को यह देखकर आश्चर्य हुआ कि उसे धक्का देकर तट पर पहुँचाने का वह काम एक डालफिन का था। वैज्ञानिकों का विश्वास है कि यदि डालफिन जमीन पर रहती तो कुत्ते का स्थान ग्रहण करके मनुष्य की सेवा करती।''

रामू ने ह्वेल के शिकार के विषय में पूछा, "ऐसा क्यों है कि दिन प्रतिदिन ह्वेल की संख्या घटती जा रही है? ये बहुत ही सीधे-सादे तथा हानिरहित प्राणी हैं। मुझे समझ में नहीं आता कि मनुष्य प्रकृति के इन सुन्दर विशाल प्राणियों को क्यों मार डालता है?''

वैज्ञानिक ने आगे विवरण दिया, "ह्वेल की खोज की एक बहुत रोचक ऐतिहासिक कहानी है जो अभी तक चली आ रही है। नौवीं शताब्दी के अन्त में नार्वे में एक ह्वेल संबंधी औद्योगिक संस्था स्थापित की गई थी। सत्रहवीं तथा अठारहवीं (17वीं-18वीं) शताब्दी में उत्तरी ध्रुव (आर्कटिक) में पायी जाने वाली ह्वेल को शिकार के लिए विस्तृत रूप से खोजा गया। यहाँ तक कि ह्वेल के विलोपन की सम्भावना भी दिखाई दी। तब ह्वेल-शिकारियों ने उष्णकटिबंधीय तथा उपोष्ण पानी में स्पर्म ह्वेल को शिकार के लिए खोजा। उन्नीसवीं शताब्दी में स्पर्म ह्वेल को पृथ्वी के चारों ओर खोजा गया। स्पर्म ह्वेल बहुत ही धीमी गति से चलने वाली सामुद्रिक मछली है तथा वे नाव पर बैठे हाथ द्वारा फेंके गये मत्स्यभाले (Harpoons) द्वारा पकड़ी जाती हैं। इसके अलावा इन जानवरों की चर्बी अधिक मोटी होने के कारण वे मर जाने पर भी प्लवमान रहती हैं। इस कारण इनको आसानी से पकड़ा जाता

है। सन् 1925-26 के आसपास तिमिलिंगन कारखानों द्वारा प्रेरित नार्वे का जहाज *ल्यान्सिँ* (Lancing) इनकी खोज के लिए रवाना हुआ।

ब्ल्यू ह्वेल की संख्या 1931-32 में 30,000 थी। मत्स्य शिकार के फलस्वरूप सन् 1954 में ब्ल्यू ह्वेल की संख्या गिरती हुई 12,000 तक पहुँच गई थी तथा सन् 1963 में इसकी संख्या 650-1950 के बीच रह गई।''

"मैंने ह्वेल के संबंध में बहुत सुना है,'' रामू ने कहा, "क्या आप मुझे उनकी प्राप्ति तथा भोजन सम्बन्धी विवरण दे सकते हैं''?

"हाँ जरूर, क्यों नहीं,'' वैज्ञानिक ने कहा– "***ब्ल्यू ह्वेल*** का एक परिध्रुवीय वितरण है। वे अधिकतर 20° दक्षिण अक्षांश* से 65° दक्षिण अक्षांश के अन्दर पायी जाती हैं। पिग्मी ब्ल्यू ह्वेल अधिकतर मैरियन द्वीप, आइल्स क्रोजेट, आइल्स कारबुलेन के आसपास पायी जाती हैं। इनका विभाजन अधिकतर उप-अंटार्कटिका में है तथा इनकी प्राप्ति 40° द.अ. से 55° द.अ.* तथा 0-80° देशान्तर** के बीच प्रतिबंधित क्षेत्रों में है। फिन ह्वेल का समान रूप से परिध्रुवीय वितरण होता है। ब्ल्यू ह्वेल की भाँति फिन ह्वेल दक्षिण की ओर अपना स्थान परिवर्तित नहीं करती। ***मिंक ह्वेल*** बहुत बड़ी संख्या में अटलांटिक महासागर, हिन्द महासागर तथा दक्षिण-पश्चिम प्रशान्त महासागर में पायी जाती हैं। ***स्पर्म ह्वेल*** विश्व के सभी सागरों में विद्यमान हैं। इनमें से केवल वयस्क नर ह्वेल अंटार्कटिका के दक्षिण में काफी दूर तक चली जाती हैं। ***कीलर ह्वेल*** अंटार्कटिका के जल में अधिकतम मात्रा में पायी जाती हैं। नीचे लिखी तालिका में दक्षिण गोलार्द्ध में ह्वेल की संख्या का भूतकाल तथा वर्तमान काल का विवरण दिया गया है –

तालिका - 3

जाति	*भूतकाल (हजार संख्या में)*	*वर्तमानकाल (हजार संख्या में)*
ब्ल्यू ह्वेल	150-210	4-5.8
पिग्मी ब्ल्यू ह्वेल	10	5-7.4
फिन ह्वेल	400	78.2-85.2
हम्प वैक ह्वेल	90-100	3-3.5
मिंक ह्वेल	–	258.3-305.2
स्पर्म ह्वेल	170	71
कीलर ह्वेल	–	145-247

* अक्षांश = Latitude

** देशांतर = Longitude

विभिन्न विशेषज्ञों के मतानुसार एकत्रित आंकड़ों की यह एक अनुमानित तालिका है। (सी सी ए एम एल आर के वैज्ञानिक संगठन द्वारा प्रस्तुत कागजातों लेखों में से दिया गया है)।

ह्वेल का भोजन संबंधी विवरण इस प्रकार है। ब्ल्यू ह्वेल अधिकतर अंटार्कटिक सागर से क्रिल खाती हैं। ये लगभग दो टन क्रिल एक दिन में खाती हैं। ये बसन्त ऋतु में कमजोर शारीरिक दशा में अंटार्कटिका में पहुँचती हैं तथा जल्दी ही चार या इससे अधिक कुछ महीनों में मोटी हो जाती हैं। इस समय इनका शारीरिक वजन कम से कम 50% अधिक हो जाता है। ये सर्दियों में अपनी शक्ति बनाये रखने के लिए गर्मियों में ग्रहण (एकत्रित) किए गए क्रिल का उपयोग करती हैं।''

रामू ने पूछा, "क्या आप मुझे इन सब मछलियों के पानी में तैरने के संबंध में कुछ बता सकते हैं?''

वैज्ञानिक ने समझाया, "सभी मछलियों में तैरने के लिए थैली होती हैं जिसमें हवा रहती है। इसका अर्थ यह है कि वे पानी में अपने भार का सन्तुलन रख सकती हैं। इसलिए ये पानी में अधिकतर ऊपर नीचे होती रहती हैं तथा पनडुब्बी की भांति कार्य करती हैं। पूंछ के लम्बे पंख मछलियों को पानी में तैरने में सहायता करते हैं। पीठ तथा नीचे पंख होने से मछली पानी में पलटती नहीं। अंस पख (Pectoral Fins) मछलियों के सूक्ष्म संचलन तथा गोते लगाने में भी सहायक हैं। यह जानना जरूरी है कि गठन में मछलियां इस प्रकार सुगठित होती हैं कि उनके किसी भी प्रकार के चालन में कोई बाधा नहीं होती।''

वैज्ञानिक ने रामू से कहा, "अब मैं सील मछलियों के विषय में कुछ बताना पसन्द करूंगा।''

रामू को यह विषय बहुत दिलचस्प लगा। उसने कहा–"हाँ-हाँ, मैंने पेंग्विन की पुस्तक *(पेंग्विन के देश में*–लेखक *डा. सै.ज. कासिम* और *श्री पी.एन. मुकर्जी)* में सील तथा ह्वेल के संबंध में काफी पढ़ा है। इससे मेरी उत्सुकता और भी अधिक बढ़ गयी है। कृपया मुझे प्रकृति के इन प्राणियों के संबंध में और भी अधिक दिलचस्प बातें बताइये।''

वैज्ञानिक ने आरम्भ किया–"आठ प्रकार की सील मछलियाँ अंटार्कटिका के दक्षिण में पाई गई हैं। इनमें से चार अंटार्कटिका की असली सील मछलियाँ हैं, जैसे–*क्रैबीटर सील,* (Crabeater Seal), *लियोपार्ड सील* (Leopard Seal), *रॉस सील* (Ross Seal), तथा *वेडेल सील* (Weddell Seal)। दो प्रकार की सील मछलियाँ उप अंटार्कटिका की सील हैं, जैसे–*दक्षिण ऐलिफेंट सील* (Southern Elephant Seal) और *अंटार्कटिका फर सील* (Antarctic Fur Seal)। चार प्रकार की वास्तविक *अंटार्कटिक सील* में से क्रैबीटर, लियोपार्ड और रॉस सील परिध्रुवीय वितरण के अन्तर्गत समुद्री बर्फ पुंज क्षेत्र की हैं जबकि वेडेल सील अधिकतर तट लग्न बर्फ में पायी जाती हैं।

बिखरा हुआ बर्फ पुंज 30% से 70% पानी की सतह को घेरकर गर्मी का आवास प्रदान करता है। अंटार्कटिका महाद्वीप के चारों ओर ऋतु के अनुसार बर्फ पुंज उत्तर से दक्षिण तक वातावरण में परिवर्तन लाता है। अत: बर्फीले क्षेत्र गर्मी में कम हो जाने के कारण क्रैबीटर सील दक्षिण की ओर चली जाती हैं। पतझड़ के समय समुद्र में ज्यों ही बर्फ जमनी आरम्भ होती है क्रैबीटर सील उत्तर की ओर अलग रूप से चली जाती हैं। शरद ऋतु के आरंभिक समय में अगस्त से अक्टूबर तक क्रैबीटर सील उत्तरी भाग के बर्फीले क्षेत्र में पायी जाती हैं। ऐसा देखा गया है कि छोटी क्रैबीटर सील बहुत अधिक संख्या में गहरे प्लावी क्षेत्रों में रहती हैं क्योंकि वे लियोपोर्ड सील के आक्रमण से डरती हैं।

लियोपार्ड सील भी समुद्री बर्फ पुंज में पायी जाती हैं। उनका भोजन क्रिल तथा क्रैबीटर सील है जो अंटार्कटिका के जल में पायी जाती हैं। रॉस सील गहरे बर्फीले क्षेत्र में पायी जाती हैं।

इन सबके विपरीत दूसरी बर्फीली सील यथा बेडेल सील मुख्यत: महाद्वीप के पास तटलग्न बर्फ के साथ सम्बद्ध हैं।

सील के संबंध में एक बहुत रोचक कहानी है। ह्वेल डुबकी लगाने से पहले एक गहरा सांस लेती हैं जबकि सील सांस छोड़ती है। सील तेज तैराक तथा गहरी डुबकी

लगाने वाला जानवर है। **वेडल सील** जो कि विशाल संख्या में अंटार्कटिका तथा उसके आस-पास पायी जाती है, पानी के अन्दर 40 मिनट तक रह सकती है तथा 600 मीटर की गहराई तक डुबकी लगाती है।''

"आप कैसे जानते हैं कि कितनी गहराई तक सील डुबकी लगा सकती है?'' काफी समय के पश्चात् रामू ने बीच में पूछा।

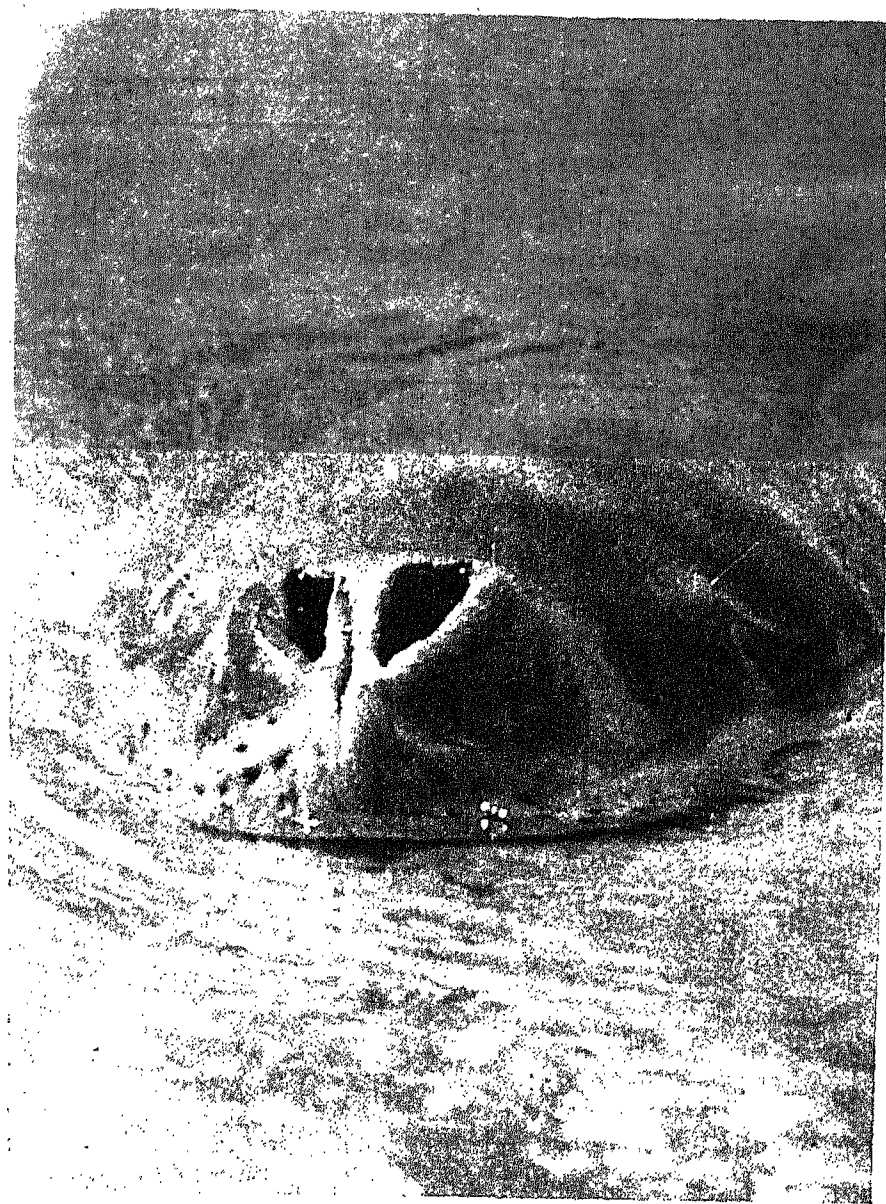
"अमरीकी वैज्ञानिक जिन्होंने यह आविष्कार किया उन्होंने गहराई नापने का यंत्र सील के गले में बांध कर गहराई को नापने में सफलता प्राप्त की।

सील के झुण्ड में सबसे विशाल सील सदरन ऐलिफेंट सील है। नापने पर लम्बाई 5 मीटर तथा वजन 2,200 किलोग्राम (2.2 टन) पाया गया। ऐलिफेंट सील अंटार्कटिका के चारों ओर पायी जाती हैं।

समस्त सीलों में से सबसे भयानक सील लियोपार्ड सील है, (चित्र नं. 6)। ये लड़ाकू प्रकृति की होती हैं और स्क्विड, मछली, पेंग्विन तथा सील के बच्चों का भक्षण करती हैं।

वालरस (Walrus) अधिकतर उत्तरी समुद्र के जल में पाये जाते हैं। वे करीब चार मीटर लम्बे तथा वजन में 1.2 टन हैं। वे बहुत अधिक मात्रा में भोजन ग्रहण करते हैं। चिड़ियाघर में वालरस को 60 किलो मछली प्रतिदिन खाते हुए देखा गया है। इनके हाथी जैसे दांत होते हैं। इसलिए इनको ऐलिफेंट सील के नाम से पुकारा जाता है। इन्हीं दांतों के लिए इनका शिकार किया जाता है। एक दूसरे प्रकार की सील फर सील है, इनकी खाल बहुत कीमती तथा उपयोगी होती है। इसलिए इनका शिकार किया जाता है।''

"मनुष्य ही बहुत बेरहम शिकारी है'', रामू ने दुखभरी आवाज में कहा।

"हाँ तुम ठीक कहते हो,'' वैज्ञानिक ने कहा। "जो कुछ भी उत्तम तथा सुन्दर वस्तु है, जो कुछ भी प्रकृति की देन है मनुष्य ने लोभवश उसका विनाश किया है। बर्फ पुंजों में पायी जाने वाली विभिन्न प्रकार की अंटार्कटिका सील की आकलित संख्या इस प्रकार है। (एस सी ए आर/एस सी ओ आर **1983 से प्राप्त**)।

चित्र 6 : लियोपार्ड सील

क्षेत्र तथा दिनांक	*क्रैबीटर*	*लियोपार्ड*	*वैडल*	*रॉस*
वैडल सागर	9422150	171538	291944	25566
आमुंडसेन/वैलीगंसआउसेन	1193365	48619	45815	21631
ओटस और जार्ज V कोष्ट्स	472424	23194	64869	63964
विल्क्स लैंड	1179849	86860	49462	16889
क्वीन माऊडलैंड	1059125	11224	285584	9976
हैलीव रीजन	1093702	63503	20978	22413
	14420615	**404938**	**758652**	**160439**

उपरोक्त आकलन के अनुसार–

"अंटार्कटिका के समस्त प्राणी जगत में सील की संख्या लगभग 15,744,644 है। **क्रेबीटर सील** के रहन-सहन के विषय में जानकर तुम्हें खुशी होगी। वे भी अपने एक परिवार में रहती हैं। जब नर को मादा तथा एक बच्चा मिल जाता है तब वे एक परिवार के रूप में अलग हो जाते हैं। वे बसन्त के प्रारम्भ होते ही ऊँचे बर्फ के किनारों में जाकर बसते हैं। यदि कोई अन्य नर (सील) वहाँ पहुँचता है तो पिता सील उसे वहाँ से चेतावनी देकर भगा देता है। प्रत्येक परिवार अपना वास स्थान 50 मीटर त्रिकोण में बनाता है।

दूसरी ओर ***लियोपार्ड*** सील बर्फपुंज क्षेत्रों में अकेली रहती हैं। उनके लिए परिवार का निर्माण कोई महत्व नहीं रखता। यदि कोई नर सील उनके परिवार के पास चला जाता है तो अधिक परवाह नहीं करते हैं।

रॉस सील का भी अपने परिवार से खास लगाव नहीं है। अन्य तीन प्रकारं के सीलों की भांति, वेडलसील तट के पास ज्वार भाग में घने बर्फ के ऊपर रहती हैं। जब मादा अपने बच्चों को दूध पिलाती हैं तब नर ज्वार दरार के पास विस्तृत पानी क्षेत्र में पहरा देते हैं।"

"मुझे उनके भोजन के बारे में कुछ बताइये" रामू ने अनुरोध किया।

वैज्ञानिक ने कहा–"क्रेबीटर सील का भोजन प्रधानत: क्रिल है, लियोपार्ड सील विभिन्न प्रकार के शिकार करती हैं– जैसे क्रिल, स्क्विड, मछली, पैंग्विन तथा सील आदि। अनेक तरह की मछलियाँ तथा क्रिल रॉस सील के उदर में पायी जाती हैं।

वेडलसील अपने भोजन में मछलियाँ, स्क्विड, क्रस्टेशिआ तथा क्रिल इत्यादि ग्रहण करती हैं।''

रामू ने कहा, "मैं समुद्र के उस जीवन्त प्राणी के विषय में और भी जानना चाहता हूँ जिनको हम भोजन में ग्रहण नहीं करते परन्तु उनके विषय में हमने बहुत कुछ सुना है।''

"मुझे तुम्हारा प्रश्न समझ में नहीं आया'', वैज्ञानिक ने कहा। "तुम्हारा मतलब शार्क आदि है?''

"हाँ हाँ, आप मुझे ***शार्क, समुद्री हाथी, स्क्विड*** तथा ***आक्टोपस*** इत्यादि के विषय में कुछ बताइये।''

"ठीक है,'' वैज्ञानिक ने कहा, "मैंने तुम्हें अभी तक ह्वेल और सील के बारे में बताया। अब मैं तुम्हें समुद्र के और भी अद्भुत जीव जन्तुओं के विषय में एक एक करके बताऊँगा।''

"धन्यवाद, कृपया आगे का विवरण दीजिए'', रामू ने अनुरोध किया।

वैज्ञानिक ने आगे का विवरण प्रारंभ किया– "गहरे समुद्र में सबसे खतरनाक जीव शार्क है। मनुष्य शार्क से डरता है। परन्तु सबसे आश्चर्यजनक बात है कि अधिकतर शार्क मनुष्य के लिए हानिकारक नहीं है। ऐसा देखा गया है कि 300 प्रकार की शार्कों में से केवल 27 प्रकार की शार्क ही मनुष्य के लिए घातक हैं और वे मनुष्य पर आक्रमण करती हैं। जो शार्क समुद्र में पाई जाती हैं वे बहुत प्राचीन युग की हैं। जिस प्रकार मछलियों में हड्डी पाई जाती है उसी प्रकार शार्क का कंकाल कार्टिलेज के रूप में बना हुआ पाया जाता है।

शार्कों की जीवित रहने की शक्ति बहुत प्रबल होती है। ऐसा कहा जाता है कि शार्क का जबड़ा निकाल लिये जाने के उपरान्त भी वह तैरने की कोशिश करती रही हैं। शार्क कई प्रकार की होती हैं। सबसे बड़ी शार्क–***ह्वेल शार्क*** (Whale Shark) के नाम से जानी जाती है। यह अटलांटिक, हिन्द तथा प्रशान्त महासागर के उष्ण जल में पायी जाती हैं। इसकी लम्बाई लगभग 19 मीटर होती है। मनुष्य को भोजन के रूप में यह ग्रहण नहीं करती हैं। ***बास्किंग शार्क*** (Basking shark) की लम्बाई

लगभग 15 मीटर होती है। यह मनुष्य को भोजन के रूप में ग्रहण करती है। सबसे छोटी शार्क *मीडवाटर शार्क* (Midwater shark) के नाम से जानी जाती है। इसकी लम्बाई केवल 15 सेमी. के लगभग होती है। अधिकतर शार्क उष्णकटिबंधीय या उसके आस-पास के जल में पायी जाती हैं। कुछ शार्क शीतोष्ण तथा आर्कटिक जल में भी पाई जाती हैं। तुम्हें यह जानकर आश्चर्य होगा कि सभी प्रकार की शार्क समुद्र में नहीं रहती हैं। इनमें से कुछ नदी तथा झील में भी पायी जाती हैं। रामू तुमने अवश्य ही लैटिन अमरीका में, झील निकारागुआ (Lake Nicaragua) का नाम सुना होगा। कई नर भक्षी शार्क इस झील में भी पाई जाती हैं।

कुछ प्रकार की शार्क समुद्री सतह में पाई जाती हैं तथा कुछ प्रकार की शार्क गहरे समुद्र में रहना पसंद करती हैं। साधारणतः, शार्क बादामी रंग की होती हैं। इसकी पीठ के भाग का रंग गहरा तथा पेट के भाग का रंग हल्का होता है। इनमें कुछ रंग बिरंगी शार्क भी पाई जाती हैं, जैसे ***जेबरा शार्क, कारपेट शार्क*** इत्यादि।

अब मैं शार्क के शरीर के ढांचे के विषय में बताऊँगा। शार्क का अगला भाग बहुत नुकीला होता है। शरीर के दोनों तरफ और नेत्रों के पीछे पांच खुले क्लोम छिद्र होते हैं। प्रत्येक छिद्र के पास में अंस पख होते हैं जो दूसरी हड्डी वाली मछलियों के जैसे नहीं होते। ये अंस पख मजबूत होते हैं। परन्तु अपने रुकने के लिए इनका प्रयोग नहीं कर सकते। सामने के युग्म अंस पख पीछे के श्रोणि पख से अधिक विशाल होते हैं। सामने के युग्म अंस पख हवा के उड़ान में वायुयान की तरह पानी में ऊपर उठने में सहायता करते हैं। रामू एक बहुत रोचक विषय तो यह है कि यदि कोई शार्क तैरना बन्द कर दे तो वह तुरंत डूबना आरम्भ कर देती है। क्योंकि इसके पास तैरने की थैली नहीं होती है और इसका घनत्व समुद्र के जल के घनत्व से अधिक होता है। तैरने की शाश्वत् गति शार्क को न केवल डूबने से बचाती है बल्कि पानी में क्लोम द्वारा ऑक्सीजन लेने में भी सहायता देती है। यदि शार्क के मुंह में पानी चला जाय तो वह अपने मुंह को बन्द कर देती है जिससे पानी क्लोम छिद्र में न जा सके। और जब वे यह पानी निकालना चाहती है तब क्लोम छिद्र खुल जाता है और पानी बाहर निकल जाता है।

रामू मैं तुम्हें और रोचक बात बताऊँगा। ऐसा देखा गया है कि कई बार गोताखोर स्थिर शार्क को पानी में खींचकर या धक्का देकर फिर से सचेत कर देते हैं और उसको पुन: तैरने के लिए मजबूर कर देते हैं। तुम शार्क को पानी में पीछे खींचकर अपने काबू में कर सकते हो। शार्क अपने सूंघने की शक्ति द्वारा भोजन का शिकार करती है। नजदीक आने से इनके देखने की शक्ति बहुत प्रबल हो जाती है। कुछ शार्क में चेतन शक्ति इतनी अधिक होती है कि वह धीमी आवाज़ भी सुन सकती है।''

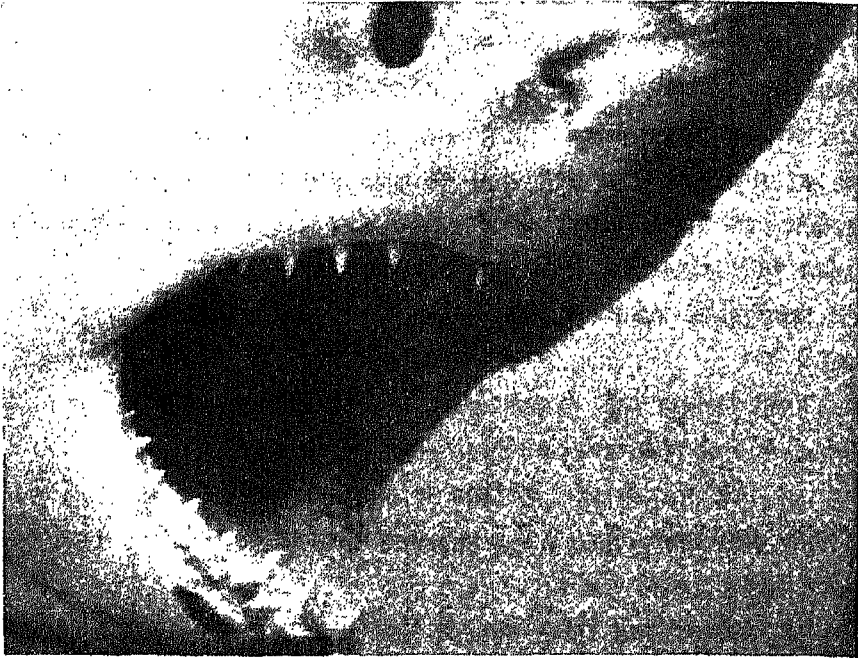
वैज्ञानिक के रुकने पर रामू ने पूछा, "क्या शार्क बहुत अधिक भोजन ग्रहण करती है?''

"नहीं बिलकुल नहीं, वे जब भोजन देखती हैं तभी उसे खाती हैं। भोजन के अभाव में शार्क लम्बे समय तक बिना भोजन के रह सकती है।

अब तुम्हें नरभक्षी शार्क के विषय में बताऊँगा। समस्त नर भक्षी शार्क में से ***विशाल श्वेत शार्क*** (Great White Shark) सबसे प्रसिद्ध हैं (चित्र-7)। मनुष्य इससे सबसे अधिक भयभीत होते हैं।

यह पृथ्वी की सबसे विशाल मांसाहारी मछली है। इसकी औसत लम्बाई लगभग 5 मीटर तथा वजन 520-760 किलोग्राम होता है। दूसरी भयंकर शार्क, ***टाइगर शार्क*** (Tiger Shark) है (चित्र-8)। यह भी नरभक्षी शार्क है। इसकी लम्बाई लगभग 4 मीटर होती है। इसके बाद ***माको*** (Mako), ***हैमर हेड*** (Hammer Head) आती हैं।''

"शार्क के आक्रमण का क्या कारण है?'' रामू ने पूछा।

"निश्चय ही प्रथम कारण है—भूख। परन्तु यह देखा गया है कि उनका पेट भरा होने पर भी वे कभी-कभी नाव पर आक्रमण कर देती हैं। पानी की सतह पर कभी-कभी हलचल आदि होने पर भी प्राय: वे आक्रमण करने के लिए मजबूर हो जाती हैं। नाव का नोदक (Propeller) शार्क को अपनी ओर आकर्षित करता है। मैं तुम्हें एक रोचक कहानी बताऊँगा। बुजार्ड्स खाड़ी (Buzzards Bay) मसाचुसेटस में दो तैराकों को एक शार्क ने निशाना बनाया। एक तैराक, जो पानी की सतह पर अपने शरीर के एक तरफ से तैर रहा था (यानि एक हाथ से तैर रहा था दूसरा हाथ पानी में कोई हरकत नहीं कर रहा था) जिसके कारण जल में कम हलचल हो रही

चित्र 7 : विशाल श्वेत शार्क

थी, उसको शार्क ने छोड़ दिया किन्तु दूसरा, जो पानी में सीधे तैर रहा था, उस पर शार्क ने आक्रमण किया। उसके पैर को शार्क ने काट लिया। पैर कट जाने के पश्चात् उसकी मृत्यु हो गई।

चित्र 8 : टाइगर शार्क

तुमने प्रसिद्ध समुद्र विशेषज्ञ ***जॉं कुस्तो*** (JEAN COUSTEAU) के विषय में अवश्य सुना होगा। कई प्रकार की शार्कों के साथ अनेक बार उनका सामना हुआ। उनका कहना है कि शार्क के स्वभाव के संबंध में कुछ कहा नहीं जा सकता। ये कभी-कभी आक्रमण भी कर सकती हैं या कभी-कभी श्वेत शार्क जैसी भयानक शार्क भी बिना किसी प्रकार का आतंक पैदा किये तीव्र गति से भाग जाती है।

वैज्ञानिकों ने पता लगाया है कि पानी का ताप शार्क के आक्रमण में एक महत्वपूर्ण स्थान रखता है। ऐसा पाया जाता है कि सबसे अनुकूल ताप 20°-21° सेल्सियस है। परन्तु 12° सेल्सियस में भी शार्क को आक्रमण करते हुए पाया गया है। देखने में हैमरहेड सबसे विकृत और भयानक शार्क है जबकि विशाल ब्ल्यू शार्क देखने में सभी प्रकार के शार्कों में सुन्दर होती है।

अब मैं तुम्हें नरभक्षी शार्क के खतरे के संबंध में और भी जानकारी दूँगा। द्वितीय विश्वयुद्ध के प्रारंभ में एक जर्मन पनडुब्बी ने अंग्रेजों के एक युद्धपोत को प्रस्फोटित करके उसे दक्षिण अंटलांटिक महासागर में डुबा दिया। पोत में सवार 450 आदमियों में से आधे से कम बच सके। यह निश्चित माना गया कि आधे व्यक्तियों को शार्क खा गयी। इन सब घटनाओं के बाद नाविक तथा वायुयान चालक शार्क ग्रस्त जगह में जाने से डरते थे। उनका कहना था कि यदि उनका जहाज़ या हवाई ज़हाज़ डूब जायेगा तो उन्हें नरभक्षी शार्क से कौन बचायेगा? एक बड़ी लम्बी खोज के बाद यह पाया गया कि तीन प्रकार के पदार्थों से शार्क को तेजी से हटाया जा सकता है। वे हैं ***मैलिक*** (Maleic) ***ऐसिड, कापर सल्फेट,*** तथा ***अमोनियम एसीटेट***। शार्क को भगाने वाली गोलियाँ भी तैयार की गयी जिनको समुद्र में फैंककर इनको हटाया जा सकता है।''

अब रामू ने पूछा–''कौन से ऐसे देश हैं जिनका तटीय जल शार्क द्वारा ज्यादातर संक्रमित हैं?''

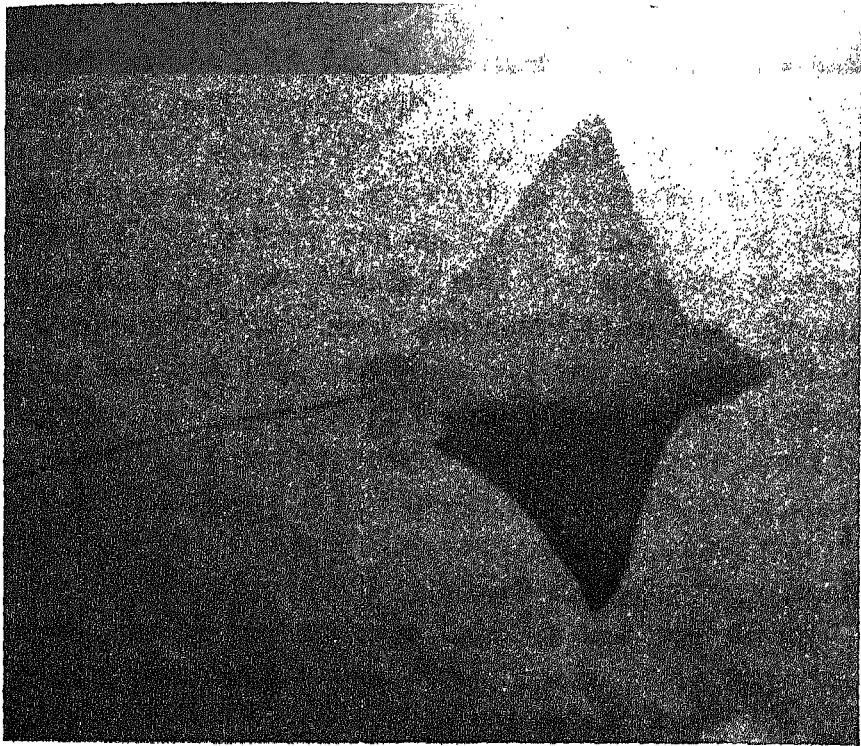
''संयुक्त राष्ट्र अमरीका, अंटार्कटिका तथा दक्षिण अफ्रीका आदि देश हैं,'' वैज्ञानिक ने उत्तर दिया। ''शार्क संबंधी अपने विषय को समाप्त करने से पहले मैं तुम्हें और कई बातें बताऊँगा। गहरे जल की अपेक्षा उथले जल में, यहाँ तक कि

1.5 मीटर से कम होने पर भी, शार्क के आक्रमण की संभावना अधिक होती है। शार्क के संबंध में दूसरा रोचकपूर्ण विवरण खोजने पर ज्ञात हुआ कि शार्क स्त्री की अपेक्षा पुरुष पर अधिक आक्रमण करती है। इसका पहला कारण यह है पुरुष, स्त्री की अपेक्षा पानी में बहुत अधिक सक्रिय रहते हैं। तथा दूसरा कारण यह भी है कि शार्कों की सूंघने की शक्ति तीव्र होने के कारण, उनको पुरुष के शरीर की गंध, स्त्री के शरीर की गंध की अपेक्षा अधिक आकर्षित करती है और साथ ही एक कारण यह भी देखने में आया है कि स्त्री के प्रसाधन सामग्री की गंध शार्क को प्रतिकर्षित करती है। यह भी देखा गया है कि पानी में संपूर्णरूप से डूबे हुए व्यक्ति पर ये आक्रमण कम करती हैं जबकि तैरते हुए व्यक्ति पर आक्रमण ज्यादा करती हैं।''

रामू ने पूछा, "शार्क की तस्वीरें कैसे खींचते हैं? विशेषरूप से उनकी जो नरभक्षी शार्क होती हैं?''

वैज्ञानिक ने उत्तर दिया, "कभी-कभी पानी में बुलबुले पैदा करके शार्क के लिए रुकावटें पैदा की जाती हैं जिससे इनकी फोटो ली जा सके। परन्तु शार्क इन बुलबुलों को भी पार कर जाती हैं। ऐसी स्थिति में एक पिंजरा तैयार किया जाता है जिसके अंदर रहकर शार्क के फोटोग्राफ लेते हैं तथा शार्क के व्यवहार का अध्ययन निकट से करते हैं।''

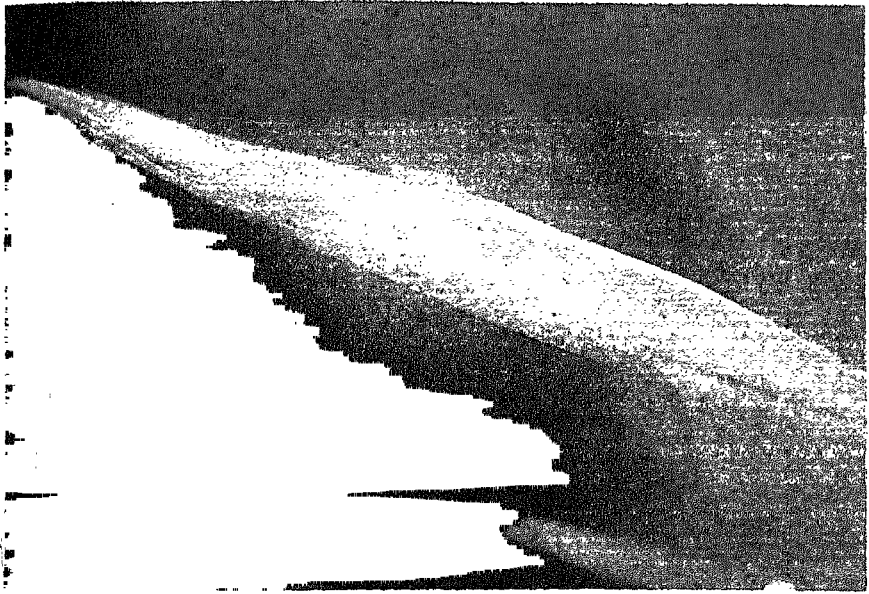
इसके बाद रामू ने पुन: पूछा, "मैं यह जानना पसन्द करूँगा कि मनुष्य के लिए और कौन-सी खतरनाक समुद्री मछलियाँ हैं?''

"ओ हाँ,'' वैज्ञानिक ने कहा, "मैंने तुम्हें रे (Ray) मछली के विषय में कुछ नहीं बताया। रे, शार्क के परिवार से ही संबंधित होती है। कुछ लोगों का विश्वास है कि यह अधिक भयानक नहीं होती। परन्तु यह सत्य नहीं है। रे के काटने से मनुष्य की मृत्यु हो जाती है। *विद्युत* रे (Electric Ray) या *तारपिडो* रे (Torpedo Ray) विभिन्न प्रकार से विद्युत की भाँति आघात देने में समर्थ होती हैं। रे को विभिन्न स्थान पर विभिन्न नाम से पुकारा जाता है। जैसे– *डेविल फिस* (Devil Fish), *ईगल* रे (Eagle Ray) (चित्र-9), *शार्क* रे (Shark Ray,) तथा *सॉ फिश* (Saw Fish) इत्यादि हैं।

चित्र 9 : ईगल रे

रे की 350 प्रकार की जातियाँ पायी जाती हैं। ये अधिकांश समय समुद्रतल पर व्यतीत करती हैं जहाँ पर ये कीचड़ तथा रेत में से काई तथा कीटभक्षण भी करती हैं। इनके अस पख विशाल तिकोन पख की तरह होते हैं। रे इन पखों की सहायता से तरंगित गति से तैरती हैं। इनकी लम्बी पूंछ तैरने में कम किन्तु प्रतिरक्षा अंग के रूप में अधिक प्रयुक्त होती हैं। दूसरी मछलियों की भाँति रे भी अपना रूप बदलती हैं जिससे वह समुद्रतट पर समा सके। ये अपने को रेत तथा कीचड़ के बीच छिपा कर विश्राम करती हैं। ***मान्ता रे*** (Manta Ray) वृहत आकार की होती हैं। कभी-कभी इसका अंस पख 6.7 मीटर तक होता है। यह लम्बाई में 5.2 मीटर तक होता है। बाहमास (Bahamas) के निकट सबसे विशाल रे पकड़ी गयी जिसका

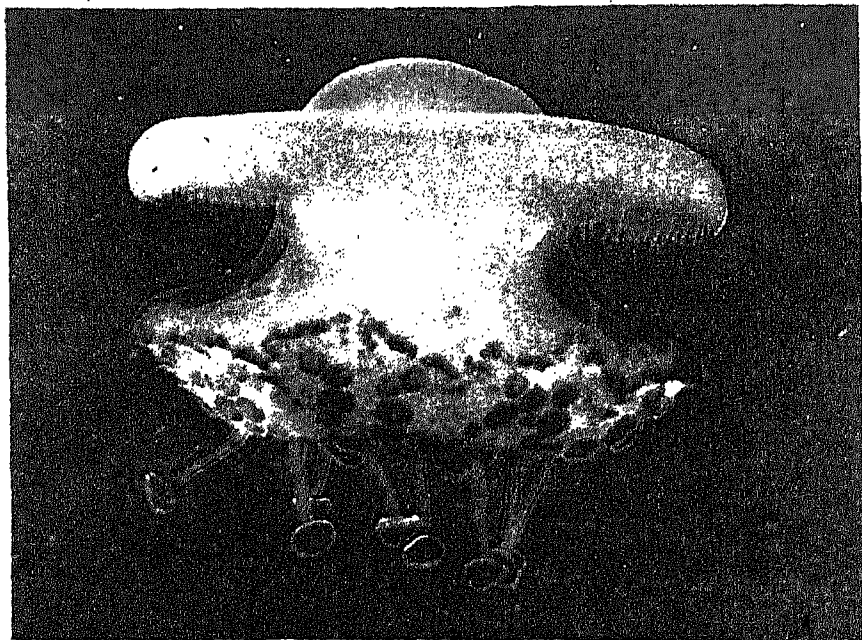
वजन 1360 किलोग्राम था। रे भी स्तनधारी होती हैं। रे सामान्यत: शांत तथा उत्सुक प्रकृति की होती है। इनकी अपरिसीमित शक्ति तब दिखाई देती है जब ये शिकारी के मत्स्य भाले (Harpoon) के सम्मुख आती हैं। उस समय ये नौका को पलटने में समर्थ हो जाती हैं। यह जानकर तुम्हें आश्चर्य होगा कि जब ये उछलकर पानी के अन्दर आ गिरती हैं उस समय ऐसा गर्जन होता है जो बहुत दूर से सुनाई देता है। तारपिडो या इलेक्ट्रिक रे मान्ता रे की अपेक्षा अधिक भयानक होती है। इस प्रकार की रे सबसे शक्तिशाली विद्युत झटके उत्पन्न करती है जिससे मनुष्य घायल हो जाता है। समुद्र का जल स्वच्छ जल की अपेक्षा अधिक विद्युत वाहक होने से तारपिडो या इलेक्ट्रिक रे मछलियाँ अधिक विद्युत प्रवाह उत्पन्न करके अपने शिकार को चौकन्ना कर देती हैं। इलेक्ट्रिक रे की आँख छोटी होती हैं। ये उष्णकटिबंधीय (Tropical) तथा शीतोष्ण (Temperate) समुद्री जल में पायी जाती हैं। ये दो मीटर की लम्बाई तक वृद्धि पाती हैं तथा इनका आकार गोलाई में आता है। ये 220 वोल्ट तक विद्युत उत्पन्न कर सकती हैं।''

रामू अब अपने विषय को बदलना चाहता था, "क्या आप मुझे ***ऑक्टोपस*** (अष्टभुज) के संबंध में कुछ बता सकते हैं? नावों पर आक्रमण करने के संबंध में हमने इसके विषय में बहुत कुछ सुना है।"

वैज्ञानिक ने सरसतापूर्वक उत्तर देते हुए कहा– "***ऑक्टोपस*** के विषय में कुछ विवरण देने से पहले मैं ***स्क्विड्स*** (Squids) के विषय में कुछ बताना चाहूँगा। ऑक्टोपस तथा स्क्विड्स ये दोनों ही सामुद्रिक शंख-जातीय अकशेरूकी (Invertebrate) या रीढ़ की हड्डी रहित जानवर हैं। एक विशाल स्क्विड पृथ्वी का सबसे भारी अकशेरूकी जानवर हैं (चित्र-10)। अधिकतर स्किवड का शरीर पतली नली के आकार का होता है जिसके एक ओर कुछ पख होते हैं। इनके मस्तिष्क से आठ चूषक हाथ बाहर की ओर आते हैं तथा एक जोड़ा लम्बा पकड़ने वाला पतला कोमल अंग होता है। यही कोमल पतला अंग नीचे चूषक हाथ से संगलित होकर शिकार को पकड़ता है। सबसे विशाल स्क्विड जो कनाडा में पकड़ा गया वह 14 मीटर लम्बा था, जिसमें 6 मीटर शरीर का अंग और मस्तिष्क थे, बाकी अंग उसका लम्बा पतला टेंटेकल्स थे। नार्वे में मनुष्य प्राय: सामुद्रिक दानव के विषय में चर्चा करते थे।

चित्र 10 : स्क्विड

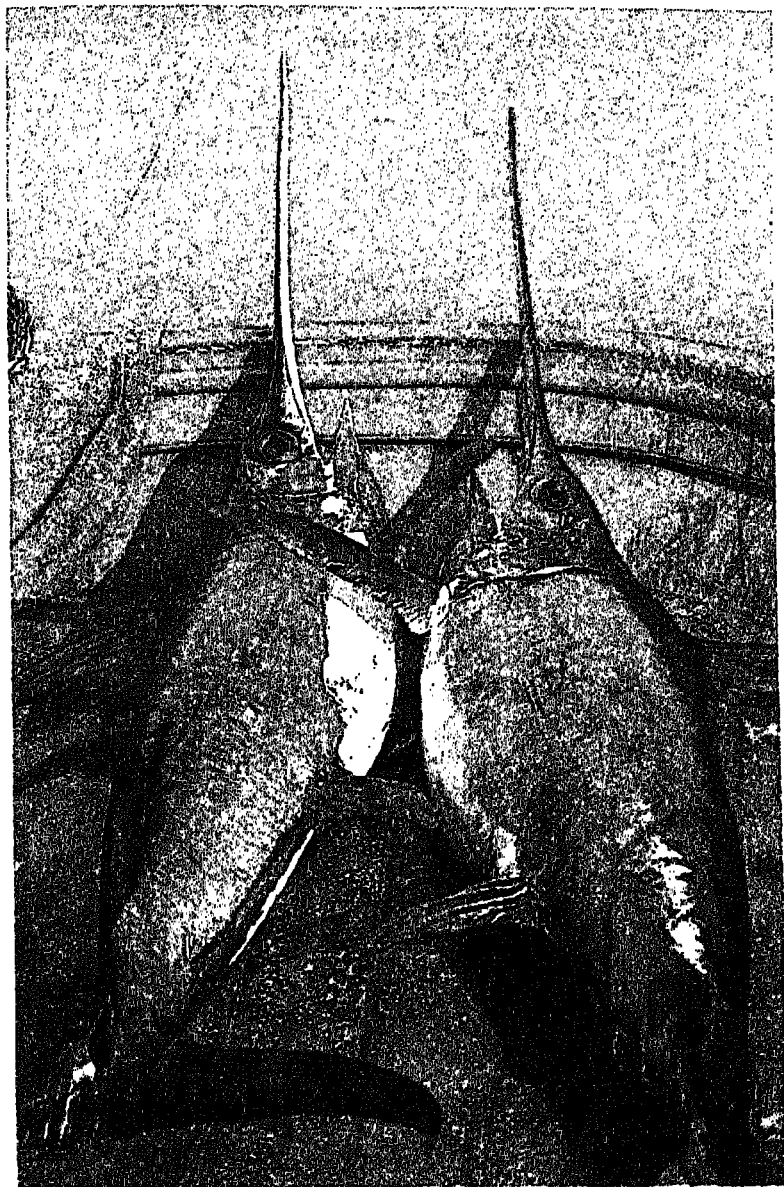
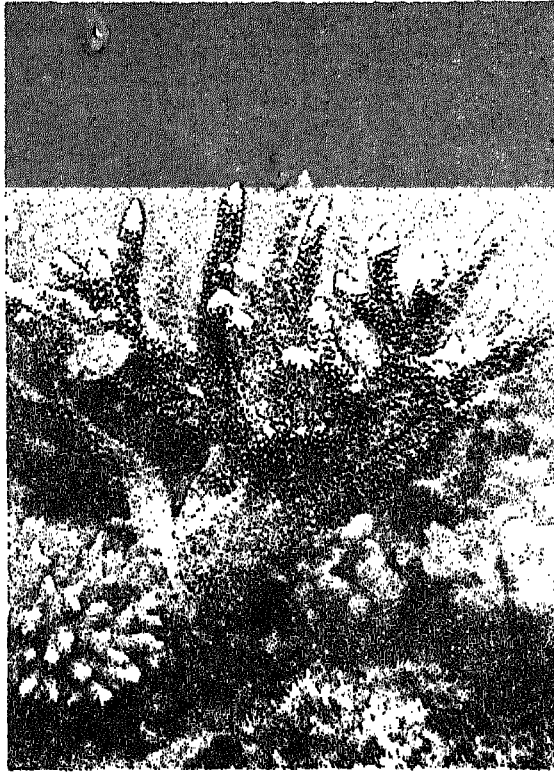
शायद वे ही विशाल स्क्विड्स थे। स्क्विड सतह पर बहुत कम पाया जाता है। यद्यपि स्क्विड बहुत विशाल है फिर भी इन पर स्पर्म ह्वेल आक्रमण करता है। दोनों काफी देर तक लड़ते हैं। स्क्विड स्पर्म ह्वेल के सामने परास्त हो जाता है तथा स्पर्म ह्वेल उसे खा लेती है। यह उस समय देखा गया है जब स्पर्म ह्वेल के मर जाने पर उसके पेट में स्क्विड का ताजा शरीर पाया गया।''

रामू ने फिर कहा– ''मैं दूसरे दिन एक बहुत रोचक पुस्तक *'टॉयलरस आफ दी सी'* पढ़ रहा था। मैं लेखक का नाम भूल गया हूँ। इस पुस्तक में एक आदमी तथा एक ऑक्टोपस में लड़ाई हुई। आदमी मर गया। मुझे बताइये कि क्या ऑक्टोपस इतना भयंकर है? साधारणत: कहा गया है कि ऑक्टोपस को पकड़ना बहुत जोखिमपूर्ण है। क्या यह सच है?''

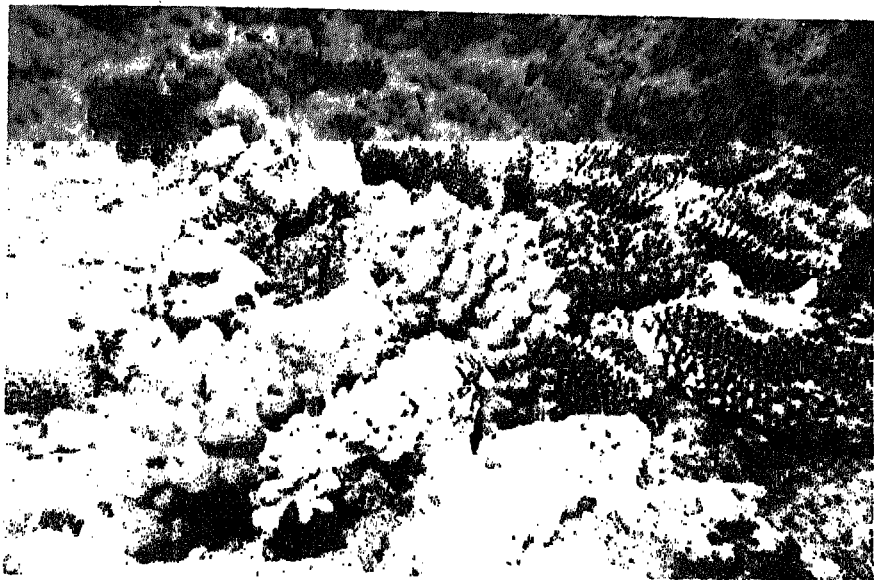
वैज्ञानिक ने मुस्कराकर उत्तर दिया, ''तुमने बहुत ही रोचक विषय के बारे में पूछा है किन्तु अभी सामुद्रिक जानवर के विषय में कहानी समाप्त नहीं कर सकते

चित्र 11 : जेली फिश

क्योंकि अभी तक ऑक्टोपस के विषय में कुछ नहीं कहा गया। जिस लेखक का नाम तुम भूल रहे थे वे हैं फ्रांस के कहानीकार *विक्टर ह्यूगो* (VICTOR HUGO)। जब कोई किसी को बहुत जोर से पकड़ता है तो हम उसकी तुलना ऑक्टोपस के पकड़ने के तरीके के साथ करते हैं। तुम्हें जानकर आश्चर्य होगा कि यह सच्चाई इतनी भयंकर नहीं है।''

वैज्ञानिक ने कहा, ''मुझे *जेली मछली* के बारे में बताना चाहिए (चित्र-11) यह प्रवाल जाति की होती है। किन्तु यह मनुष्य के लिए बहुत हानिकारक होती है। उत्तरी आस्ट्रेलिया के समुद्रतट पर चेतावनी के रूप में बोर्ड लगे रहते हैं ज़िनपर लिखा रहता है *'सावधान! बिच्छू दंश बूटी आ रही है।'* यह इतनी विषैली होती है कि अगर किसी आदमी को काट लेती है तो सात मिनट के अंदर उसकी मृत्यु हो जाती है।

आओ अब तुम्हें *सोर्ड फिश* (चित्र-12) के बारे में कुछ बताते हैं। इस फिश का

चित्र 12 : सोर्ड फिश

चित्र 13 : प्रवाल

ऊपरी जबड़ा, लम्बाई में 2 मीटर से 4 मीटर तक होता है। ब्रिटिश म्यूजियम (Museum) में एक जहाज की ऐसी टिम्बर रखी गयी है जिसमें देखा जा सकता है कि ***सोर्ड फिश*** की तीक्ष्ण चोंच 5.5 सेन्टीमीटर अंदर तक चली गयी है। ***सोर्ड फिश*** दूसरी मछली को इसी तीक्ष्ण चोंच से मार देती है और बाद में उसे खा लेती है।''

वैज्ञानिक ने आगे विवरण दिया– ''सामुद्रिक जीवित प्राणियों का इतिहास तब तक पूरा नहीं होता जब तक तुम्हें मैं ***प्रवाल*** (कोरक) के संबंध में कुछ ज्ञान न दे दूँ (चित्र–13, 14, 15)। तुमने अवश्य ही समुद्री तट पर प्रवाल भित्ति के विषय में सुना होगा। ये सामुद्रिक यातायात में नाविकों के लिए बाधा उत्पन्न करते हैं।

चित्र 14 : समुद्री प्रवाल *(आई.एन.ओ. के सौजन्य से)*

चित्र 15 : समुद्री प्रवाल *(आई.एन.ओ. के सौजन्य से)*

विभिन्न प्रकार के प्रवाल उष्णकटिबंधीय देश के गर्म जल में अधिकतर 60 मीटर से कम गहराई में पाये जाते हैं।''

''अधिक गहराई में क्यों नहीं?'' रामू ने पूछा।

''क्योंकि प्रवाल के ऊतक के अंदर छोटे-छोटे कई एक कोशीय जीव होते हैं जिसको अपना भोजन तैयार करने के लिए रोशनी की आवश्यकता होती है। इस प्रक्रिया को ***प्रकाश संश्लेषण*** (Photosynthesis) कहा जाता है।''

''प्रकाश संश्लेषण के लिए इनको कार्बन-डाई-ऑक्साइड कहाँ से प्राप्त होती है?'' रामू ने पूछा।

''तुम ठीक कहते हो,'' वैज्ञानिक ने उत्तर दिया। ''प्रवाल शरीर में साँस द्वारा कार्बन-डाई-ऑक्साइड अर्जित करते हैं। प्रवाल मांसाहारी होते हैं। ये अधिकतर रात्रि में ही क्रियाशील होते हैं तथा स्पर्शक (Tentacles) द्वारा अपना शिकार पकड़ते हैं।

सामुद्रिक धारा में पाये जाने वाले छोटे जीव प्राणिप्लावक (Zooplankton) कहलाते हैं। प्रवाल स्पर्शक द्वारा शिकार के रूप में प्राणिप्लावक पकड़कर उसको काटते हैं और उसका अंगाघात कर देते हैं। फिर स्पर्शक द्वारा उसको अपने नली जैसे मुंह में धकेल देते हैं। नली के अन्दर से ग्रासिका को आहार नली में पहुंचा देते हैं। जहाँ विशिष्ट शरीर कोशिकाएँ भोजन का पाचन करके तत्वों का अवशोषण करती हैं।

अभी तक हमको प्रवाल से निर्मित होने वाली तीन प्रकार की संरचनाओं के बारे में ज्ञान हो सका है। ये हैं– ***तटीय प्रवालभित्ति*** (Fringing Reefs), ***प्रवाल रोधिका*** (Barrier Reef), तथा ***प्रवाल द्वीप वलय*** (Atolls)।

प्रवाल के विशाल समूह में विभिन्न प्रकार के पौधे तथा जीव-जन्तु प्राकृतिक रूप से रह सकते हैं। प्रवाल में बने गड्ढे और कोटर मोलस्क (मृदुकवची), ***केकड़ा*** (चित्र-4), ***झींगा*** (चित्र-3) आदि के लिए भोजन प्रदान करते हैं तथा उनके छिपने के लिए संरक्षण देते हैं। प्रवाल सुन्दर सामुद्रिक प्राणी हैं। तुम्हें यह जानकर दुख होगा कि प्रवाल का जीवन अब खतरे में है। कुछ मछलियाँ जैसे ***क्राउन ऑफ थॉर्नस*** (Crown of Thorns), ***स्टारफिश*** इत्यादि प्रवाल का भक्षण करती हैं। मनुष्य भी प्रवाल भित्ति की खुली खान से चूना-पत्थर प्राप्त करते हैं तथा तेल प्राप्ति की खोज में

वेधन (Boring) करते हैं। इससे गाद (Silting) उत्पन्न होती है, इस प्रकार के कार्य प्रवाल के लिए खतरे के कारण हैं क्योंकि प्रवाल स्वच्छ जल में ही रहते हैं। इसलिए वे गंदगी या गाद में अधिक समय तक जीवित नहीं रह सकते। इस प्रकार प्रवाल को होने वाली क्षति के कारण विश्व में उसके रोचक अध्ययन तथा उससे मिलने वाले आनन्द से मनुष्य जाति वंचित रह जायेगी। प्रवाल के लिए खतरा होने से, प्रवाल के अन्दर रहने वाले विविध प्रकार के समुद्री प्राणियों को भी क्षति पहुँच सकती है। फिजी द्वीप के नजदीक प्रवाल भित्ति अब सूखे प्रवाल की शुष्क भूमि में बदल गये हैं।''

रामू ने पुन: अनुरोध किया, "क्या आप मुझे समुद्र में भोजन-भण्डार तथा समुद्र में पाये जाने वाली विभिन्न प्रकार की मछलियों तथा भारत में पाये जाने वाली समस्त मछलियों के उत्पादन के विषय में बता सकते हैं?''

वैज्ञानिक ने कहा, "यह उत्तम बात है कि तुम बहुत उत्सुक हो। कृपया ध्यान से सुनो। मैं तुम्हें इस संबंध में बताने जा रहा हूँ।

जैसा हम जानते हैं कि समुद्र ने 71% पृथ्वी की सतह को घेर रक्खा है और इस भाग को सूर्य की पर्याप्त रोशनी प्राप्त होती है। सूर्य की पर्याप्त रोशनी प्राप्त होने से समुद्र में भोजन पदार्थ के अधिकतम मात्रा में होने की संभावना है। सन् 1970 में 28920 लाख टन भोजन धरती पर उत्पन्न किया गया जबकि सामुद्रिक उत्पादन करीब 600 लाख टन मात्र था।''

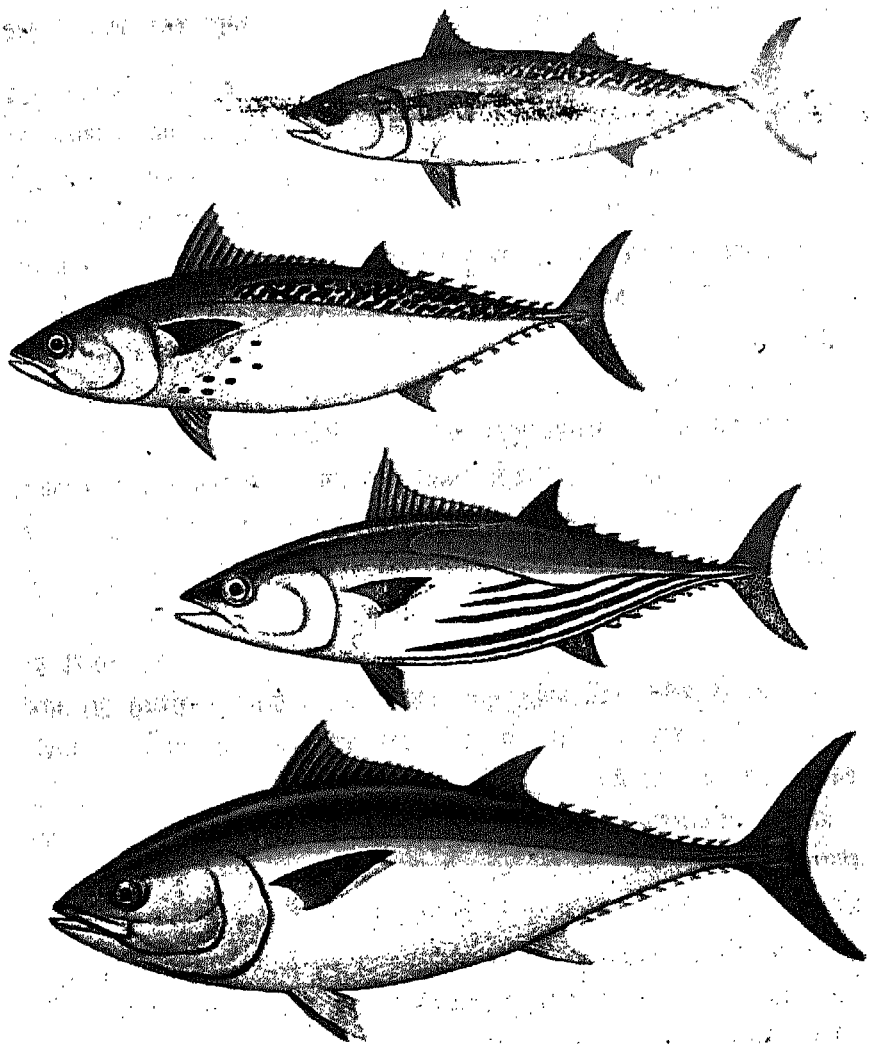
रामू ने बीच में पूछा– "कृपया मुझे उन मछलियों के विषय में बताइए जो भारतीय समुद्री तट के समीप पायी जाती है।''

वैज्ञानिक ने कहा, "हाँ-हाँ मैं तुम्हें इस विषय में भारत की स्थिति के बारे में बताने जा रहा हूँ।''

"भारतवर्ष में प्रति व्यक्ति मछली का औसत उपभोग (Per capita Consumption) मात्र 3.2 किलोग्राम प्रतिवर्ष है। यह विश्व के एक तिहाई से भी कम है। जापान में मछली का औसत उपभोग 86 किलोग्राम प्रतिवर्ष है। दक्षिण पूर्वी एशियाई देशों में 30 से 50 किलोग्राम, बंगलादेश में 7.5 किलोग्राम, श्रीलंका में 14.9 किलोग्राम तथा पाकिस्तान और नेपाल में 2.8 और 0.8 किलोग्राम प्रतिवर्ष है। इन आंकड़ों से यह स्पष्ट है कि भारत में मछली का औसत उपभोग अत्यन्त कम है।

जैसा कि तुम जानते हो कि भारत तीन ओर जल से घिरा हुआ है– हिन्द महासागर, अरब सागर तथा बंगाल की खाड़ी। विभिन्न प्रकार की सामुद्रिक मछलियाँ जैसे– *सारडीन, ट्यूना, बांगड़ा* (चित्र-16), *बंबिल, पॉफेट* इत्यादि समुद्र के तटवर्गीय स्थानों में पायी जाती हैं। समुद्र के निकट की नदियाँ, चपटे प्रकार की *झींगा मछली* का उत्कृष्ट उत्पादन स्थान हैं। भारत की तट रेखा (Coastline) लगभग 7000 किलोमीटर लम्बी है। यह अनुमान है कि हिन्द महासागर में मछली का उत्पादन प्रति वर्ष 70 से 170 लाख टन हो सकता है जिसमें से भारत 50 से 90 लाख टन उत्पादन कर सकता है। परन्तु इस समय समुद्री मछली का उत्पादन लगभग 17.55 लाख टन ही है। इस प्रकार तुम देखोगे कि सामुद्रिक मछलियों का उत्पादन बढ़ाकर 4 से 5 गुना किया जा सकता है। जिस प्रकार भारत में जनसंख्या की वृद्धि हो रही है उससे अनुमान लगाया जाता है कि सन् 2000 के बाद भारत को 130 लाख टन मछलियों की आवश्यकता होगी। होने वाली कमी की पूर्ति ताजे जल से मछली उत्पादन करके होगी। वर्तमान समय में भारत में समुद्र से मछलियों के उत्पादन का विस्तृत विवरण मेरे पास है। सन् 1984-85 में समुद्री मछलियों का उत्पादन 16.98 लाख टन था जबकि सन् 1983-84 में केवल 15.19 लाख टन ही था। तुम्हें यह जानकर खुशी होगी कि समुद्र में मछली उत्पादन की सीमा में विस्तार हो रहा है। सन् 1989-90 में भारत में समुद्री मछली का उत्पादन 17.90 लाख टन था जबकि कुल उत्पादन 32.50 लाख टन था। विशेष रूप से झींगा, सारडीन, बंबिल तथा बांगड़ा मछलियाँ ही समुद्र से पकड़ी जाती हैं। भारत में पूरे सामुद्रिक मछलियों के उत्पादन का 23% केरल में पाया जाता है। दूसरा स्थान महाराष्ट्र तथा गुजरात का है और उसके बाद तमिलनाडु में मछली पकड़ने का स्थान है। इस प्रकार पश्चिमी तट पर 71% तथा पूर्वी तट पर 29% मछली पकड़ी जाती है।''

रामू बीच में बोल उठा– "मैं झींगा मछली खाना पसन्द करता हूँ। मुझे भारत में प्राप्त झींगा मछली के विषय में बताइये।''

वैज्ञानिक ने कहा, "सामुद्रिक उत्पादन में 90% झींगा मछली का उत्पादन होता है, जो अधिकतर विदेशों में निर्यात कर दिया जाता है। सन् 1985-86 में 85843

चित्र 16 : चार विभिन्न प्रकार की मछलियाँ– बाँगड़ा, पीले पंख वाला ट्यूना, धारीदार ट्यूना, नीले पंख वाला ट्यूना

टन समुद्री मछलियों का उत्पादन हुआ और विदेशों में भेजा गया, जिसका मूल्य 460.67 करोड़ रुपये था। झींगा मछली का कुल अन्तर्राष्ट्रीय व्यवसाय 5 लाख टन था जिसका मूल्य 30.2 लाख डालर (US Dollar) था। इसमें भारत का योगदान 10% का था। कुछ वर्ष पहले भारत ने जापान के बाजार में झींगा मछली व्यवसाय में एकाधिकार प्राप्त कर लिया था परन्तु अब ताइवान इस क्षेत्र में भारत से आगे बढ़ गया है। ताइवान ने जापान को सन् 1986-87 में 50,000 टन झींगा मछली भेजी जबकि भारत ने कुल 37,000 टन झींगा मछली जापान को भेजी।''

इसी समय रामू थोड़ा सोचने लगा और बाद में पूछा, "आप कृपया बताइये कि समुद्री मछलियों को कैसे पकड़ा जाता है?''

वैज्ञानिक ने जबाब दिया, "यद्यपि 1960 तक देश का लगभग समस्त उत्पादन देशज अयंत्रीकृत यानों से हुआ करता था, तथापि बाद के वर्षों में इस प्रवणता में परिवर्तन आने लगा। देश में अब समुद्री मात्स्यकी सम्पदाओं का विदोहन मूल रूप से विविध प्रकार के देशज गियरों (Gears) से हो रहा है। इसमें ट्राल नेट, पर्ससीन, ड्रिफ्ट ग्रिल नेट आदि का उपयोग करने वाली छोटी यंत्रीकृत बोट, बाहरी या भीतरी इंजन से चलने वाली देशज नावें आदि आते हैं। इसके अतिरिक्त 20 और 30 मीटर के आकार की सीमा में आने वाले बड़े पोतों का परिचालन निजी व्यक्तियों द्वारा हो रहा है।

हमारी महासागरीय सम्पदा तो बड़ी विस्तृत है लेकिन इसके साथ कुछ कठिनाइयाँ भी हैं। अभी तो यह हाल है कि हम अपने तटों में मात्र 8-10 किलोमीटर की दूरी तक ही समुद्र में जा पाते हैं, तथा अपने सीमित साधनों से मछलियाँ पकड़ते हैं। अधिक दूर जाकर मछलियाँ पकड़ने के लिए न तो हमारे पास यथेष्ट साधन हैं और न ही कुशल मानवशक्ति। रामू तुम यह सुनकर दुखी होगे कि हम यांत्रिक पोतों की कमी के कारण दूर तक नहीं जा पाते और थाइलैंड (Thailand), ताइवान जैसे देशों के शक्तिशाली यांत्रिक पोत हमारे क्षेत्रों में आकर चुपके से मछलियाँ पकड़कर ले जाते हैं।

मैं इस विषय को समाप्त करने से पहले तुम्हें ***झींगा, महाचिंग*** (Lobster),

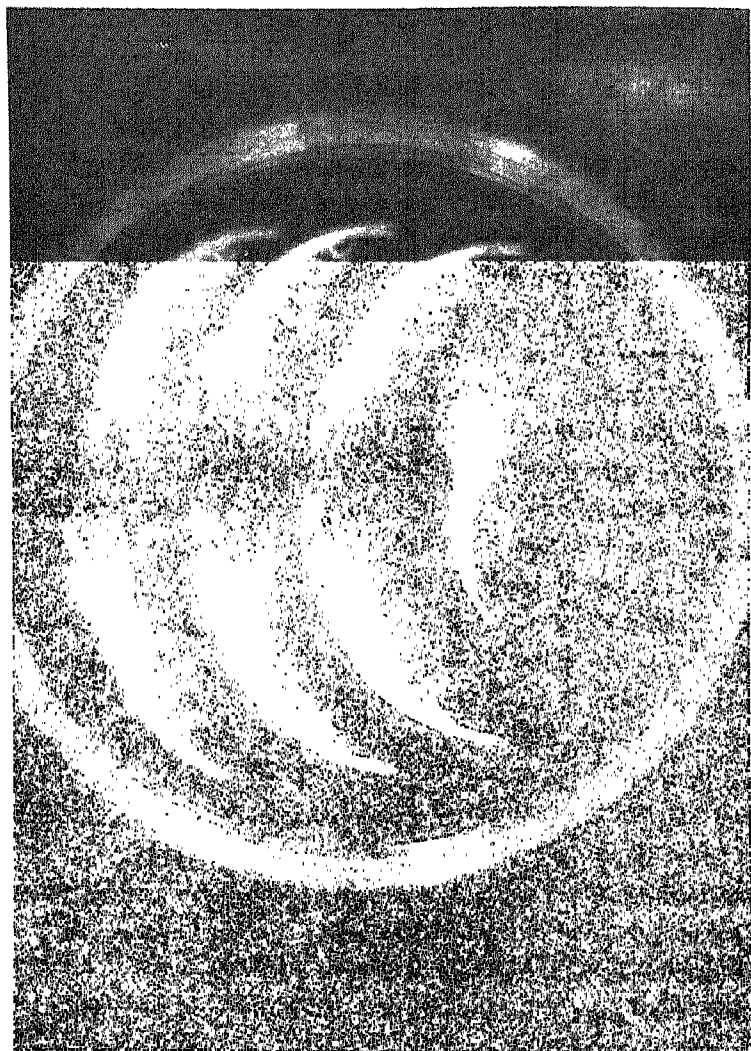
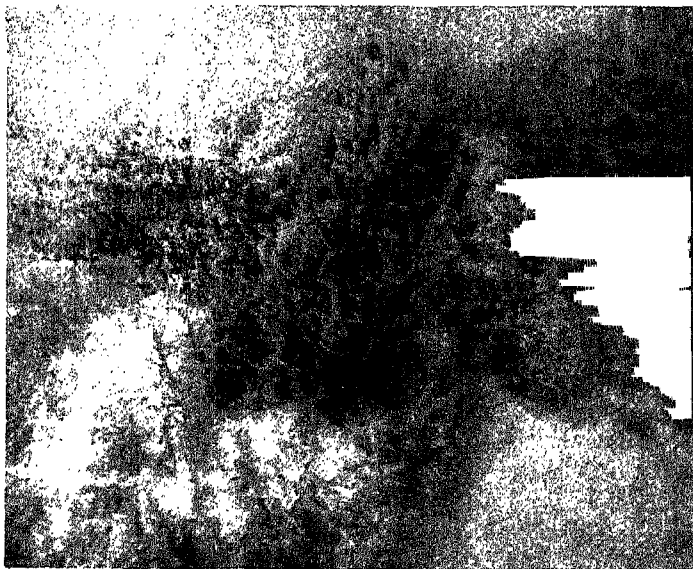
विचिंगट (Cray Fish) तथा *केकड़ा* के विषय में कुछ बताना चाहता हूँ। तुम *झींगा, महाचिंगट, मछली* तथा *केकड़े* के विषय में जानते ही होंगे जिनको मछली बाजार में बेचा जाता है। ये एक मूल्यवान संसाधन हैं। ये प्रांन तथा श्रिम्प के संबंधी माने जाते हैं। ये कठोर खोल के अन्दर रहने वाले जलचर हैं तथा देखा जाता है कि केकड़े विशाल आकृति में भी पाए जाते हैं। जापान के समुद्र में बहुत विशाल केकड़ा पकड़ा गया है। इनमें से कुछ केकड़े *मैक्रोचेरिया कैम्फेरी* (Macrocheira Kaempferi) के नाम से जाने जाते हैं। इनके पंजे एक ओर से दूसरी ओर तक 4 मीटर लम्बे होते हैं तथा बाहर की ओर फैले रहते हैं। इस प्रकार के केकड़े का कवच 45 सेंटीमीटर चौड़ा होता है। *तस्मानियन केकड़ा* (Tasmanian Crabs) 10-12 किलोग्राम के वजन का होता है तथा इसके एक जोड़े संदशिक पैर 40 सेंटीमीटर लम्बे होते हैं।

केकड़ा तथा *लॉबस्टार* अपने शरीर के अंग को त्याग कर स्वाभाविक रूप से उनकी स्थान पूर्ति कर सकते हैं (चित्र-4)। स्पेन के मछुआरे उनकी इस प्राकृतिक परिघटना से बहुत लाभ उठाते हैं। वे केकड़े या लॉबस्टार पकड़कर उनके पंजों को तोड़ लेते हैं और अभागे केकड़ों को फिर से समुद्र में फेंक देते हैं। समय के साथ-साथ उनके पंजे फिर से आ जाते हैं तथा कुछ समय बाद उनके साथ फिर ऐसा ही व्यवहार किया जाता है। लॉंबस्टार बहुत जल्दी से अपने उदर को फैलाकर कभी सिकुड़ कर तैर सकता है जिससे आवश्यकता पड़ने पर शीघ्रता से पीछे हट सकता है। इसमें संकुचन तथा प्रसारण इतना तीव्र होता है कि यह पानी से ऊपर उछलकर पानी के बाहर हवा में आ जाता है।''

"यहाँ एक और सामुद्रिक जीव का उल्लेख करना भूल गया हूँ.'' वैज्ञानिक ने कहा– "दक्षिण ध्रुव के समुद्र प्राणिप्लवक विशेषकर क्रिलों से भरपूर है (चित्र-17)।

क्रिल ज्यादातर समुद्र के पृष्ठीय स्तर में रहते हैं। ये सूक्ष्मदर्शीय प्लवकीय शैवाल का भक्षण करते हैं। जैसा कि तुमने ***पेंग्विन के देश में*** शीर्षक पुस्तक में पढ़ा था, क्रिल में प्रोटीन अधिक मात्रा में पाया जाता है।

समुद्री शैवाल (Sea Weeds) उर्वरक तथा रासायनिक तत्व के लिए और औषध निर्माण आदि के लिए उपयोग में लाया जाता है। समुद्री शैवाल द्वारा विशिष्ट

चित्र 17 . क्रिल

चित्र 18 : समुद्री शैवाल (पैडिना टैट्रोस्टोमैटिक–एन.आई.ओ. के सौजन्य से)

चित्र 19 : लाल समुद्री शैवाल (ऐकेन्थोफोरा स्पीसीफेरा–एन.आई.ओ. के सौजन्य से)

रासायनिक तत्व जैसे ऐगार ऐगार (Agar Agar), ऐल्जिनेट इत्यादि भोजन, तांतुकी, औषध निर्माण तथा औद्योगिक कार्य के लिए व्यवहार में लाये जाते हैं। समुद्री शैवाल, प्रोटीन, आयोडीन, जीव ऊर्जा, जानवरों का आहार, औषध निर्माण तथा विशिष्ट वस्तुओं के सार तत्व के निचोड़ में भी प्रयुक्त हो सकता है। इसमें खनिज सार रहने से, विशेषत: सूक्ष्म पोषक (Micronutrients), ये समुद्र तटीय रेतीली भूमि में खाद उत्पन्न कर सकते हैं। इसका सर्वेक्षण तथा खोज भावनगर में सेन्ट्रल साल्ट एण्ड मैरिन केमिकल्स रिसर्च इन्स्टीट्यूट और गोवा में एन आई ओ (N I O) ने किया है। कच्छ और सौराष्ट्र (गुजरात) में 12000 टन से अधिक मात्रा में सारगैसम (Sargassum) पाया गया है। महाराष्ट्र के तटवर्गीय प्रदेश में 210 टन सारगैसम भी पाया गया है। चित्र-18 और 19 में समुद्री शैवाल के कुछ चित्र प्रस्तुत किये गए हैं।

अन्त में मैं तुम्हें मैंग्रोव के बारे में कुछ बताना जरूरी समझता हूँ

चित्र 20 : मैंग्रोव (एकन्थस इलिसीफायलियस–*एन.आई.ओ.के सौजन्य से*)

(चित्र-20)। तुमने सुना होगा कि हर साल समुद्र के तल की ऊँचाई बढ़ती जा रही है (Sea Level Rise)। इससे सारी दुनियाँ के वैज्ञानिक आज चिंतित हैं। इसके साथ-साथ हर साल स्थल का कुछ न कुछ भाग समुद्री अपरदन (Sea Erosion) से समुद्र के अन्दर चला जाता है। समुद्रतट के पास बनी हुई मैंग्रोव इस अपरदन से समुद्रतट को बचाती है। इसके अतिरिक्त चिंगट (Shrimp) मछलियाँ मैंग्रोव से खाद्य सामग्री प्राप्त करती हैं। पारिस्थितिक दृष्टिकोण से देखते हुए, मैंग्रोव की उपयोगिता ने आजकल समुद्र विज्ञान को विशेष रूप से प्रभावित किया है।"

अध्याय 5

समुद्र से औषधि प्राप्ति

(DRUGS FROM THE SEA)

वैज्ञानिक ने कहा–

"अभी तक सामुद्रिक पौधों तथा जीवों को कच्ची सामग्री के रूप में निरापद दवाइयों तथा औषधियों के लिए प्रयोग में लाया जाता रहा है। जिन सौ या उससे भी अधिक पौधों तथा सामुद्रिक जीवों का परीक्षण किया गया है उनमें से लगभग 42 प्रकारों के अच्छे परिणाम निकले हैं। दस सामुद्रिक जीवों में उर्वरता निरोधक गुण पाये गये हैं। जब समुद्री शैवाल से उत्पन्न हुए कैल्शियम ऐल्जिनेट को कटे हुए घाव पर मरहम पट्टी के लिए प्रयोग में लाया जाता है तब उससे जेल जैसा पदार्थ तैयार होता है जो रक्त बहना रोक देता है। ऐल्जिनेट को अन्य कई औषधियों में भी प्रयुक्त किया गया है। दंतचिकित्सक भी इसका प्रयोग करते हैं। ऐगार में सल्फैटेड पॉलिसेकेराइड होता है, जिसके अन्दर कई प्रकार के ऐसे तत्व विद्यमान होते हैं जो जीवाणुओं की वृद्धि को रोक देते हैं। उनमें से एक जीवाणु हरपीस वाइरस भी है। सामुद्रिक पौधों *गेलिडियम कार्टिलेजिनियम* (Gelidium Cartilageneum) से ऐसे कुछ पदार्थ निकाले गये हैं जिसमें मुर्गी के बच्चे के अंडे में एन्फुलुएंजा बी (Influenza B) और मम्पस (Mumps) इत्यादि के जीवाणुओं को रोकने की क्षमता है। सामुद्रिक पौधों से कुछ ऐसे सरसत (Extract) निकाले जाते हैं जो रक्त में कोलेस्टेरॉल (Cholesterol) की मात्रा बढ़ने से रोकते हैं। यह पाया गया है कि इन शैवालों में कुछ ऐसे तत्व हैं जिनसे चूहे का कोलेस्टेरॉल स्तर नीचे आ जाता है।

कुछ ऐसे समुद्री शैवाल भी हैं जो जापान में भोजन के रूप में ग्रहण किये जाते हैं। क्यानिक ऐसिड एवं ऐलोक्यानिक ऐसिड नामक पदार्थ पेट के कीड़ों को मारने के लिए औषधि के रूप में प्रयोग किया जाता है। ये दोनों ही पदार्थ सागर में पाई जाने वाली डिजिनिया सिम्पलेक्स नामक शैवाल से निकाले जाते हैं। हाल ही में ऐलोक्यानिक ऐसिड की सक्रियता दूसरे क्षेत्र में भी प्रकाश में आयी है। यह ऐसिड केन्द्रीय तन्त्रिका तंत्र (Central Nervous System) में विकार पैदा करता है जिसके उपयोग से मस्तिष्क विकार में विभिन्न लक्षणों को समझने में सहायक होने के संकेत मिले हैं।

यह देखा गया है कि चूहे में एलगल पॉलिसैकेराइड द्वारा बेरियम, कैल्शियम तथा जिंक से उत्पन्न जहर को रोका जा सकता है। सामुद्रिक स्पंज कई प्रकार के होते हैं। कैरिबियन स्पंज में से एक सक्रिय पदार्थ निकलता है जो चूहे में कैंसर एवं रक्त कैंसर का (जिसे लुकीमिया नाम से जाना जाता है) निरोध करता है। भारत का सामुद्रिक किनारा काफी विशाल है और वहाँ पर पाये जाने वाले समुद्री जीव भी अनेक प्रकार के हैं। औषधि प्राप्ति की दिशा में अनुसंधान कार्य काफी पिछड़ा हुआ है। इसमें काफी संघटित प्रयास की आवश्यकता है। लगभग 6 वर्ष पूर्व इस दिशा में एक सामूहिक प्रयास प्रारम्भ किया गया था। इसके अन्तर्गत एन.आई.ओ. (गोवा), **बोस संस्थान** (कलकत्ता), एवं **केन्द्रीय औषधि अनुसंधान संस्थान** (लखनऊ) जैसे तीन संस्थानों ने भाग लिया था।

अब तुम यह देखोगे कि गहरे समुद्रतल में और क्या-क्या पाया जाता है।'' इतना कहने पर वैज्ञानिक रुक गया।

अध्याय 6

समुद्र की खनिज सम्पदा

(MINERALS FROM THE SEA)

वैज्ञानिक ने कहा, "अभी तक तुम सामुद्रिक दुनियाँ की एक सुन्दर कहानी सुन रहे थे, परन्तु यह लाखों सामुद्रिक जीवन्त प्राणियों की कहानी का एक भाग है। मैंने अभी तक तुम्हें केवल कुछ अद्‌भुत सामुद्रिक जीव-जन्तुओं का विवरण दिया है। यदि कोई सालों इसका प्रयत्न करें तो भी इन सबके विषय में पूरा विवरण देना संभव नहीं होगा। आओ, अब मैं तुम्हें कुछ निर्जीव सामुद्रिक सम्पदा अर्थात् खनिज पदार्थ, रसायन इत्यादि के विषय में जानकारी के लिये एक भू-वैज्ञानिक के पास ले चलता हूँ।''

समुद्र में छिपी हुई सम्पदा के बारे में रामू की दिलचस्पी बढ़ती गई। रामू भू-वैज्ञानिक के पास जाकर बोला, "मुझे आप सामुद्रिक खनिज सम्पदा के विषय में कुछ बताइये।''

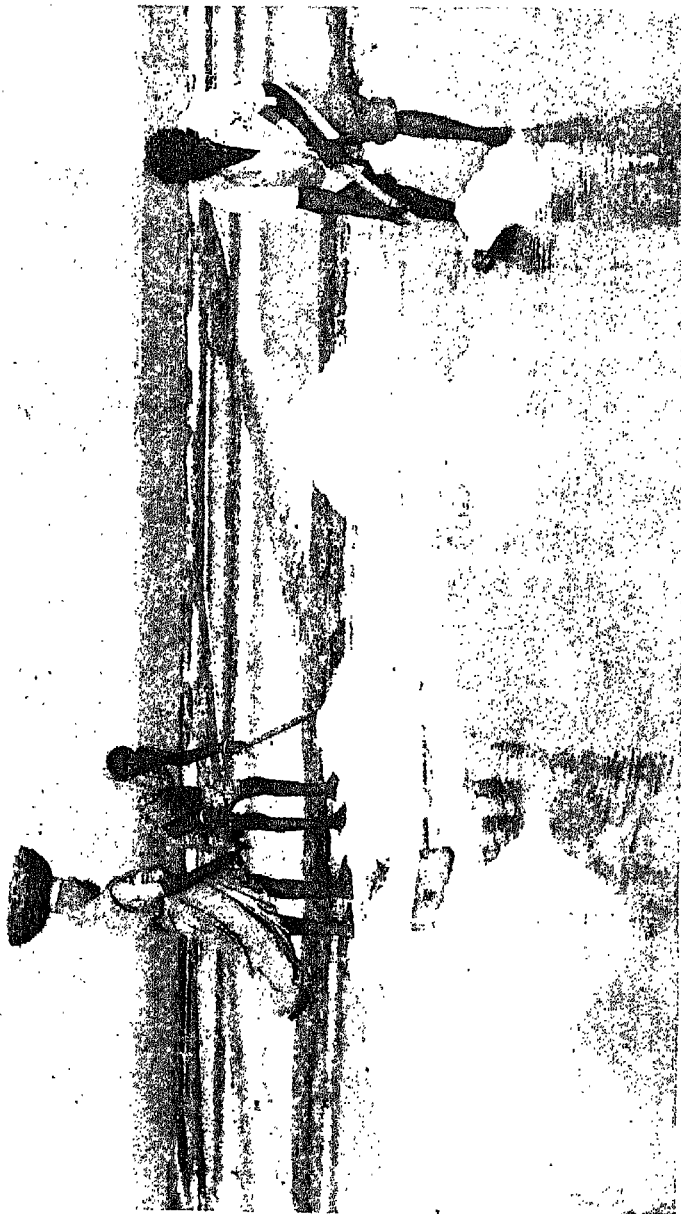
भू-वैज्ञानिक ने कहा, "जैसा कि तुम जानते हो जीवन का प्रारंभ समुद्र से ही हुआ है। अब तुम देखोगे कि समुद्र में विभिन्न प्रकार के खनिज तथा रासायनिक तत्वों का बाहुल्य है। यह शायद स्वाभाविक ही है क्योंकि समुद्र सतह पृथ्वी का ही दीर्घीकरण है। समुद्र के पानी के नीचे भूमि ही है।

बढ़ती हुई जनसंख्या तथा सभ्यता की प्रगति के साथ-साथ मनुष्य की मांगों में भी वृद्धि हुई है। अधिक मात्रा में धातु एवं खनिज की मांग के कारण इनकी प्राप्ति के लिए भू-संसाधन में लगातार कमी आ रही है। इसलिए मनुष्य नये संसाधनों की खोज में समुद्र के नीचे सर्वेक्षण कर रहा है। अब मैं तुम्हें इनके विषय में कुछ विवरण दूंगा।

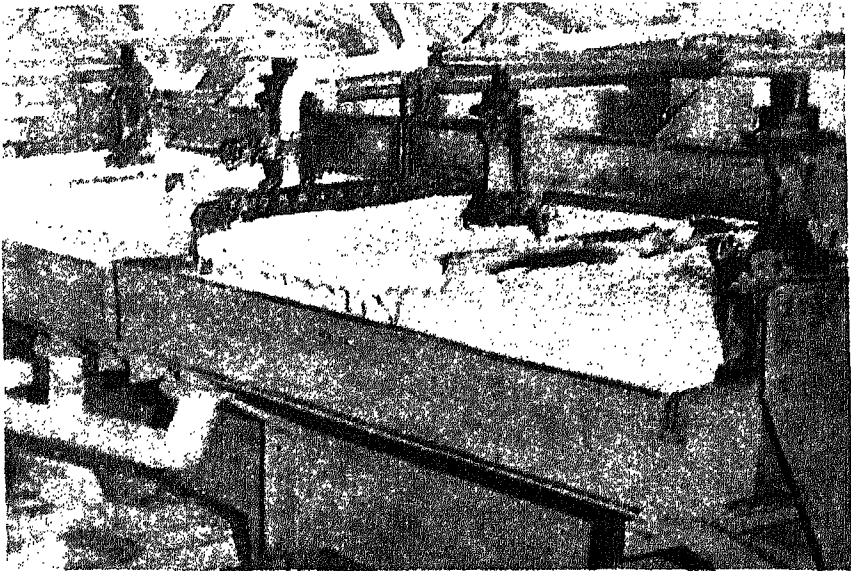
पहले मुझे सामुद्रिक रासायनिक तत्व के विषय में कुछ कहने दो। समुद्र में लगभग साठ (60) के करीब मूल तत्व पाये गये हैं उनमें से केवल छः को ही व्यापारिक रूप से लिया गया है। ये हैं सोडियम तथा क्लोरिन (साधारण लवण या सोडियम क्लोराइड के रूप में), मैग्नीशियम (उसके यौगिक पदार्थ के रूप में), ब्रोमीन एवं कैल्शियम तथा सल्फर (गन्धक, कैल्शियम सल्फेट या जिप्सम के रूप में)। कम सांद्रण होने से समुद्र में से पोटेशियम निकालना बहुत लाभकारी नहीं है, जबकि लवण निकालने के समय कुछ हद तक पोटेशियम समुद्र जल से प्राप्त हुआ।''

रामू बीच में ही पूछ बैठा, ''लवण को किस प्रकार समुद्र के जल से प्राप्त करते हैं?''

भू-वैज्ञानिक ने उत्तर दिया, ''लवण सौर तापन द्वारा वाष्पित करके कई देशों में निर्यात किया जाता है। विशिष्ट रूप से भारतवर्ष में समुद्री जल को सौर तापन द्वारा वाष्पित करके ही लवण तैयार किया जाता है। (चित्र-21)। सौर द्वारा वाष्पित करने की विधि का प्रयोग अन्य देशों जैसे– संयुक्त राष्ट्र अमरीका, चीन, फ्रांस, आस्ट्रेलिया, स्पेन, पुर्तगाल तथा दक्षिण एशिया और अफ्रीका के देशों में भी किया गया है। वर्तमान में लवण का उत्पादन भारतवर्ष में 90 लाख टन है। सन् 2000 ई. तक लवण का उत्पादन करीब 220 लाख टन तक होने की सम्भावना है।

जब नमक निकालने के लिए समुद्र जल को खुले स्थान में वाष्पित किया जाता है तो समुद्री बिटर्न प्राप्त होता है। एक टन बिटर्न से एक टन से कुछ कम नमक का उत्पादन होता है। इस बिटर्न के अन्दर 12% से 14% सोडियम क्लोराइड, 2.5% पोटेशियम क्लोराइड, 10% से 12% मैग्नीशियम क्लोराइड, 6% से 7% मैग्नीशियम सल्फेट तथा 0.2% मैग्नीशियम ब्रोमाइड पाया जाता है। पोटेशियम उर्वरक समुद्री बिटर्न से प्राप्त किये जा सकते हैं। सौर शक्ति का लाभ उठाते हुए समुद्री बिटर्न को फिर से वाष्पित करके ठोस वाष्पनज जैसे अपरिष्कृत लवण, मिश्रित लवण, तथा खाद्य लवण पाये जा सकते हैं। सोडियम सल्फेट तथा पोटेशियम उर्वरक की प्राप्ति के लिए समुद्री बिटर्न को फिर से संशोधित किया जा सकता है। सोडियम सल्फेट, कागज, कांच, तांतुकी तथा अपमार्जक उद्योग में काम में लाया जाता है।

चित्र 21 : समुद्री जल को सौर तापन द्वारा वाष्पित करके ही लवण तैयार किया जाता है। (*सैंट्रल साल्ट एंड मैरिन कैमिकल्स रिसर्च इंस्टीट्यूट, भावनगर के सौजन्य से*)।

मिश्रित लवण से पोटेशियम उर्वरक की प्राप्ति भारत जैसे कृषि प्रधान देश के लिए काफी महत्वपूर्ण है। भारतवर्ष की किसी भी भूमि में पोटेशियम निक्षेप (Potassium Deposit) नहीं है। एक बहुत उत्तम पोटेशियम उर्वरक, जिसकी प्राप्ति समुद्र की बिटर्न में होती है, पोटेशियम सियोनाइट (Potassium Schoenite) के नाम से जाना जाता है। इसका उर्वरक मूल्य बहुत अधिक है। इस विषय में गुजरात के भावनगर शहर में **सेन्ट्रल साल्ट एण्ड मैरिन केमिकल्स रिसर्च इन्स्टीट्यूट** ने बहुत ही अनुसंधान का काम किया है। चित्र-22 में पोटेशियम सियोनाइट तैयार करते हुए आरंभिक संयंत्र को दिखाया गया है।

समुद्र जल तथा शुक्ति कोष्ठ या डोलोमाइट को साधारण कच्ची सामग्री के रूप में प्रयोग में लाकर मैग्नीशियम धातु का बहुत बड़ी मात्रा में निर्माण किया जा सकता है। यह विधि संयुक्त राष्ट्र अमरीका तथा नार्वे में प्रयोग में लाई जाती हैं। वास्तव में समस्त विश्व में मैग्नीशियम का कुल उत्पादन 1.8 से 2.0 लाख टन है। उसमें

चित्र 22 : समुद्री जल से पोटेशियम सियोमाइट–एक आरंभिक संयंत्र *(सैंट्रल साल्ट एंड मैरिन कैमिकल्स रिसर्च इंस्टीट्यूट, भावनगर के सौजन्य से)*

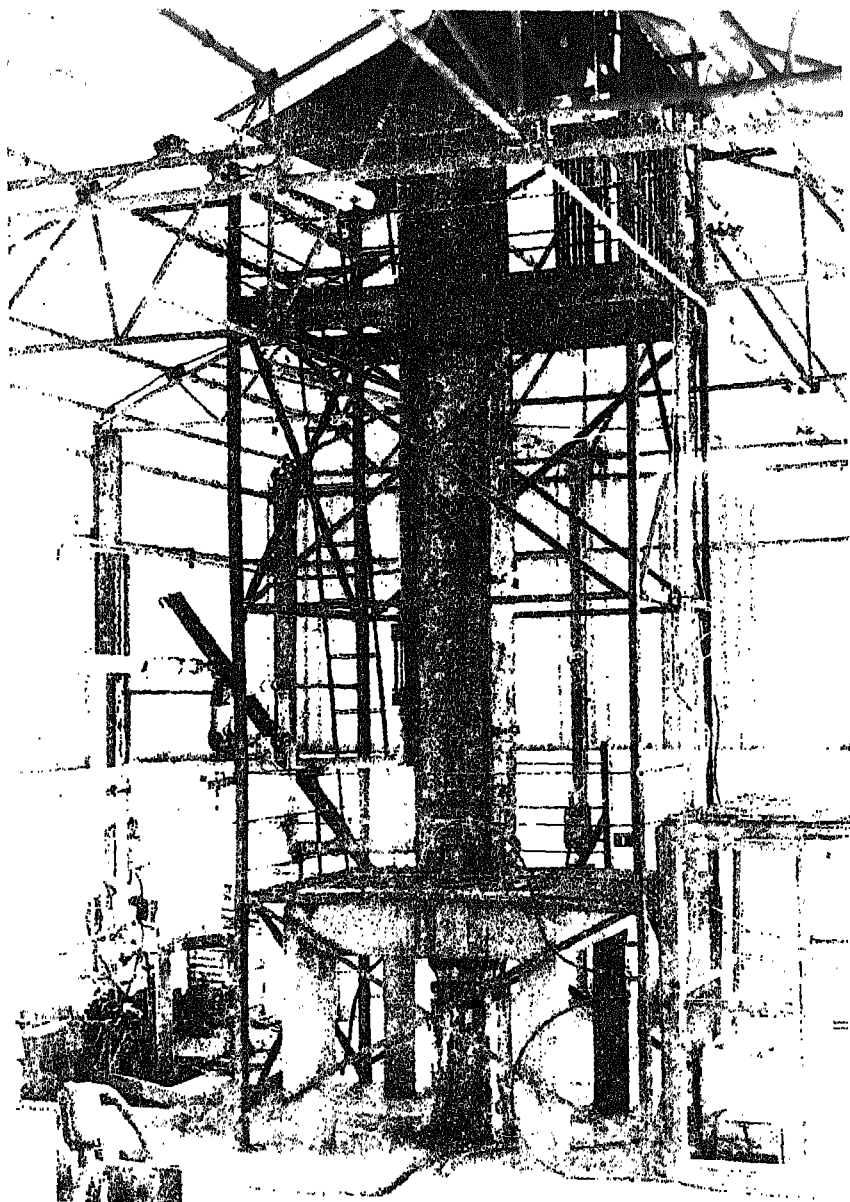
से 1.2 लाख टन का उत्पादन समुद्री जल से होता है। मैग्नीशियम धातु तथा उसके एल्युमिनियम, मैंगनीज, जैरकोनियम, थोरियम, जिंक तथा चांदी के साथ मिश्र धातु ऐसे औद्योगिक प्रयोग में लाये जा सकते हैं जहाँ हल्कापन तथा यांत्रिक गुण धर्म की आवश्यकता होती है।

समुद्री जल ब्रोमीन का एक प्रमुख स्रोत है जो कि समुद्री जल में ब्रोमाइड के रूप में उपस्थित रहता है। ब्रोमीन तथा इसके यौगिक का अधिक मात्रा में प्रयोग उत्तम प्रकार के तेल, रंग, फोटोग्राफी रसायन, कीटनाशक दवाओं तथा औषधियाँ तैयार करने में किया जाता है। संयुक्त राष्ट्र अमरीका, इंग्लैंड, फ्रांस, जापान में बहुत अधिक मात्रा में तथा इज़राइल, स्पेन, इटली, दक्षिण अफ्रीका तथा भारतवर्ष में अपेक्षाकृत कम मात्रा में, समुद्र की बिटर्न से ब्रोमीन का निर्माण किया जा रहा है। इस संबंध में यह बोलना उचित होगा कि सैंट्रल साल्ट एण्ड मैरिन कैमिकल्स रिसर्च इंस्टीट्यूट (सी.एस.एम.सी.आर.आई.) समुद्री जल से ब्रोमीन के उत्पादन के लिए उच्चस्तर का अनुसंधान कार्य कर रहा है। चित्र–23 में ब्रोमीन उत्पादन करने के लिए एक आरम्भिक संयंत्र दिखाया गया है, जिसे इस इंस्टीट्यूट ने बनाया है।

कुछ समय पहले ही जापान ने समुद्र जल का प्रयोग करते हुए टाइटेनिक ऐसिड द्वारा यूरेनियम प्राप्ति के लिए एक विधि की खोज की है।

अपतट पेट्रोलियम (OFFSHORE PETROLEUM)

यदि हम समुद्र की खनिज सम्पदा के विषय पर और विचार करें तो सर्वप्रथम हमारा ध्यान समुद्र सतह में तेल तथा गैस की प्राप्ति की ओर जाता है।

भू-वैज्ञानिकों का विश्वास है कि करीब सभी महाद्वीपों के अपतट के 200 मील तक पेट्रोलियम पाया जा सकता है। कुछ लोगों का विचार है कि और गहरी समुद्री सतह भी पेट्रोलियम के लिए उचित स्थान हो सकती है। सामान्य रूप से कहा जा सकता है कि संसार में कुल पेट्रोलियम के उत्पादन का 30% भाग अपतट स्थानों से प्राप्त होता है। यह अनुमान किया जा रहा है कि सन 1995 या उसके आसपास

अधिक बढ़ना आरम्भ हुए थे तब से तेल कम्पनियों और राष्ट्रीय सरकारों ने अपतट में तेल तथा गैस के उत्पादन में अधिक धन लगाया। हमारे देश में तेल तथा प्राकृतिक गैस कमीशन ने (Oil and Natural Gas Commission) कई विदेशी संस्थाओं के साथ संभावित अपतट स्थानों में तेल की खोज के लिए संविदाएँ (Contracts) की हैं। बहुत से स्थान ऐसे हैं जहाँ पर अभियान आरंभ हो चुका है। एक है—बंगाल के **सुन्दरबन की बेसिन,** दूसरा है—**कच्छ की बेसिन**। इनके अलावा **कावेरी बेसिन** तथा **कृष्णा-गोदावरी बेसिन** में पेट्रोलियम तथा तेल या प्राकृतिक गैस की उपस्थिति का पता चला है। परन्तु अभी तक अधिकतम प्राप्ति बंबई हाई के स्थानों में ही हुई है जहाँ उत्पादन मई 1976 में आरम्भ हुआ था। भारत में भूमि से प्राप्त तेल और अपतट से प्राप्त तेल, दोनों मिलकर हमारी घरेलू मांग का लगभग 60% पूरा करते हैं। सन् 1990-91 में भारत में कच्चे तेल (Crude Oil) का उत्पादन लगभग 320 लाख टन हुआ। तेल तथा प्राकृतिक गैस के अन्वेषण तथा उत्पादन के लिए एक विशिष्ट प्रौद्योगिकी की आवश्यकता है। इसमें भूतत्व वैज्ञानिक खुदाई, ड्रिलिंग, पंम्पिग एकत्रित करके रखना तथा रिग अनुरक्षण शामिल है। समुद्र तली से पेट्रोलियम एवं प्राकृतिक गैस निकालना सम्भव होगा या नहीं यह जानने के लिए जिस विधि का प्रयोग किया जाता है उसे भूकंपी अध्ययन (Seismic Study) के नाम से जाना जाता है। आजकल वैज्ञानिक ऊर्जा लहर समुद्र अधस्तल के विभिन्न स्थानों में भेजते हैं। ये लहरें महासागर की तली से प्रतिबिम्बित होकर ऊपर प्राप्त की जाती है। इन लहरों के अध्ययन से समुद्र पृष्ठ में उपस्थित खनिज सम्पदा के बारे में जाना जाता हैं। वर्तमान समय में ऊर्जा उत्सर्जक युक्तियाँ जैसे विस्फोटन रहित गैस (Nonexplosive Gas) तथा भूकम्पी बन्दूक (Seismic Gun) महासागर की सतह पर छोड़ी जाती है। एक और नयी प्रणाली चालू की गई है। नाव से जल के नीचे एक गोली (पैनिट्रोमीटर) समुद्री तलछट पर चलायी जाती है। यह पैनिट्रोमीटर हवा-बन्दूक (Air Gun) द्वारा चलायी जाती है जो हवा के दबाव द्वारा परिचालित होती है। यह गोली समुद्र तली के नरम रेत, गाद, तथा मिट्टी के नीचे 10 मीटर गहराई तक प्रवेश करती है।

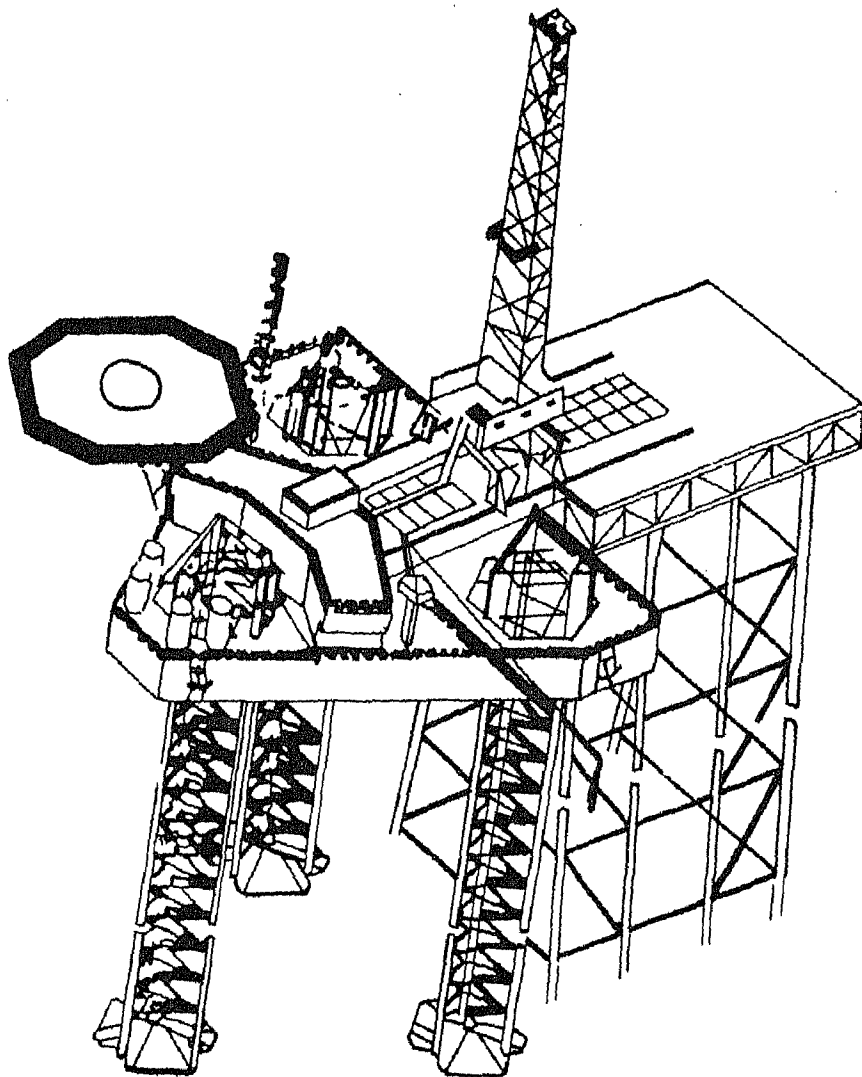
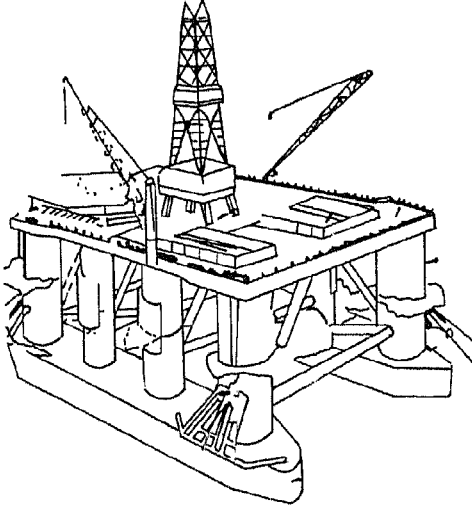
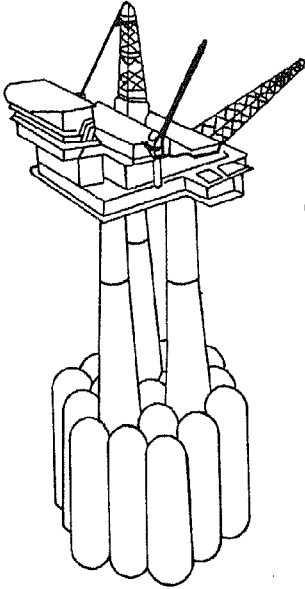
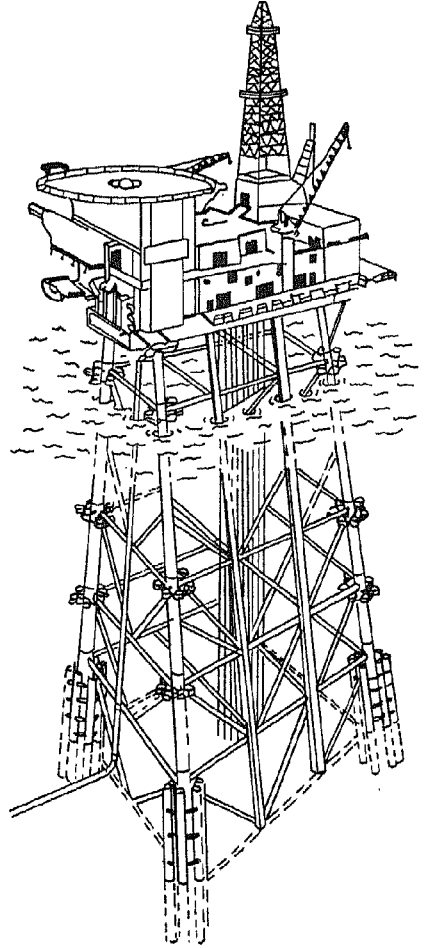
भू-वैज्ञानिक **अन्वेषण** के लिए जो माध्यम प्रयोग में लाये जाते हैं उनमें विभिन्न प्रकार के यंत्र होते हैं जैसे– **मैगनेटोमीटर** (Magnetometer), **अन्तर्जलीय कैमरा** (Underwater Camera), **विडियोटेप** (Videotape), **वाटरसैम्पलर** इत्यादि। इसके अलावा छोटी **सी पनडुब्बी** (Submersible) का भी प्रयोग किया जाता है। अधिकांश अपतट पेट्रोलियम के स्थानों में गोताखोर बहुत खतरे वाले कार्य करते हैं, जैसे– समुद्रतली का वेधन या ड्रिलिंग, वेलहैड्स और पाइप लाइन, रिग आदि के निर्माण तथा अनुरक्षण। सन् 1975 में लगभग 26 गोताखोरों की उत्तरी समुद्र (North Sea) में एक दुर्घटना में मृत्यु हो गई।

अपतटीय क्षेत्र में समुद्र तली में उपलब्ध हाइड्रोकार्बन की खोज में और प्राप्त खनिज पदार्थ के जमाव कार्य में कई प्रकार की संरचनाओं (Structure) का प्रयोग किया जाता है। अन्वेषण और खनन कार्यों में निम्न प्रकार की तकनीक का प्रयोग किया जाता है :

(क) ***जॉक अप रिग (Jack Up Rig) :*** यह त्रिकोणीय इस्पात पैरा के जोड़ से बनाये गए फ्रेम द्वारा निर्मित किया जाता है। इस प्रकार का फ्रेम रिग के तीन कोनों पर मशीनों की सहायता से ऊपर से नीचे जाने के लिए लगाया जाता है। (चित्र 24 क)। यह 107-8 मीटर गहरे पानी में अच्छा काम कर सकता है।

(ख) ***सेमिसब्मर्सिवल रिग (Semisubmersble Rig) :*** इसमें दो समानान्तर बक्से पानी में डूबे रहते हैं। इन बक्सों के ऊपर आठ खम्बे एक बड़ी छत संभाले रहते हैं (चित्र 24 ख)। यह रिग 407 मीटर से अधिक गहरे पानी में काम नहीं कर सकता।

(ग) ***जॉक अप प्लेटफार्म (Jack Up Platform) :*** यह इस्पात से बनी नली को जोड़कर बनाए गए फ्रेम द्वारा निर्मित किया जाता है। इस संरचना को समुद्रतली में नुकीले लट्ठे की मदद से खड़ा किया जाता है (चित्र 24 ग)।

(घ) ***कंक्रीट ग्रेविटी प्लेटफार्म (Concrete Gravity Platform) :*** कंक्रीट अपने भारी घनेपन के कारण आकारों का वजन बढ़ाने में मदद करती है, ताकि समुद्रतल पर यह आकार आसानी से बड़ी लहरों का सामना करते वक्त स्थिर

चित्र 24 क : जॉक अप रिग

चित्र 24 ख : सेमिसब्मर्सिबल रिग

चित्र 24 घ : कंक्रीट ग्रेविटी प्लेटफार्म

चित्र 24 ग : जॉक अप प्लेटफार्म

रह सके (चित्र 24 घ)। इस प्रकार का आकार अधिकतम 170 मीटर गहरे पानी में उपयोग में लाया जा सकता है।

उपरोक्त औजारों को और भी सुसज्जित बनाया जा सकता है जैसे इनके साथ एक गोता लगाने का निकाय संलग्न किया जा सकता है जिसमें नियंत्रण घंटी, स्थानान्तरण एवं विसंपीडन कक्षा (Decompression Chamber) तथा टी.वी. कैमरा सम्मिलित है।

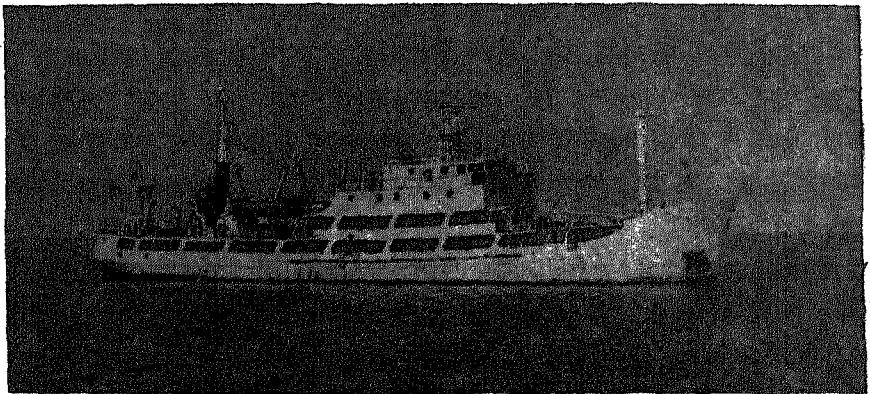
प्राकृतिक तेल तथा गैस आयोग (ओ.एन.जी.सी.) का **'सागर प्रभात'** जो एक वेधन जहाज है गोदावरी नदी के बेसिन के अपतट पर कार्य कर रहा है। अब **प्राकृतिक तेल तथा गैस आयोग** अपतट क्षेत्रों में तेल के अन्वेषण अभियानों में 70 से अधिक प्रवेधक नौकाओं का प्रयोग कर रहा है। अपतट पेट्रोलियम के संबंधित विषय को समाप्त करने से पहले यह बताना चाहता हूँ कि **प्राकृतिक तेल तथा गैस आयोग** द्वारा जो उत्पादन असम तथा गुजरात में सन् 1975 में 30 लाख टन था वह अब बढ़कर 320 लाख टन हो गया है। यह निश्चित है कि कुछ वर्षों में हम स्वयं कच्चे तेल के उत्पादन में आत्मनिर्भर हो सकेंगे। परन्तु तेल को शुद्ध करने की क्षमता को बढ़ाने की आवश्यकता है ताकि जनता में पेट्रोल तथा पेट्रोलियम पदार्थों की मांग की पूर्ति आसानी से हो सके।''

प्लेसर निक्षेप (PLACER DEPOSITS)

भू-वैज्ञानिक ने कहा, "अब मैं तुम्हें उस विषय के बारे में बताना चाहता हूँ जिसे वैज्ञानिक **प्लेसर निक्षेप** कहते हैं। ये रेत तथा बजरी के संग्रह होते हैं जिसमें खनिज जैसे–सोना, प्लैटिनम, थोरियम, जर्कोनियम, टाइटेनियम, एल्युमिनियम इत्यादि पदार्थ मिले रहते हैं। इन प्लेसर निक्षेपों का **अपक्षय** (Weathering) से अपघटन नहीं होता।''

रामू ने पूछा, "अपक्षय क्या होता है?''

जबाव देते हुए भू-वैज्ञानिक बोला, "अपक्षय पौधों तथा जीवाणुओं की एक प्रक्रिया है जिसमें भौतिक तथा रासायनिक क्रिया द्वारा चट्टानों का परिजीवित होना तथा उनका खण्डों में टूट जाना होता है। लगातार कई वर्षों से भारी खनिज पदार्थों के

चारों ओर की चट्टानें पानी में विलीन होकर विघटित हो जाती हैं। साथ ही भारी खनिज पदार्थ जिसे प्लेसर के नाम से जाना जाता है नीचे गिरकर जम जाते हैं। ये खनिज प्लेसर भारत के समुद्री तट पर पाये जाते हैं। इन्हें **काली रेत (Black Sand)** के नाम से जाना जाता है। यह काली रेत भारत के पश्चिम तट पर कन्याकुमारी से लेकर महाराष्ट्र के तट तक पायी जाती है। इन निक्षेपों में इल्मेनाइट, रूटाइल, जिरकान, तथा मोनाजाइट मिलते हैं। इसमें कुछ मात्रा में खनिज जैसे– मैगनेटाइट तथा गार्नेट भी पाये जाते हैं। इस विषय में दो वैज्ञानिक संस्थाएँ–**राष्ट्रीय समुद्र विज्ञान संस्थान** (एन.आई.ओ.) तथा **भारतीय भू-वैज्ञानिक सर्वेक्षण विभाग** (Geological Survey of India) ने अपने-अपने माध्यमों द्वारा अन्वेषण तथा सर्वेक्षण किया। **राष्ट्रीय समुद्र विज्ञान संस्थान** ने समुद्र यात्रा करने वाले समुद्री जहाज़ **'गवेषणी'** का प्रयोग किया (चित्र-25)। भारतीय भू-वैज्ञानिक सर्वेक्षण विभाग ने दो तटीय पोत– **समुद्र कौसटाव** (Samudra Kaustav) तथा **समुद्र सौधीकामा** (Samudra Saudhikama) का प्रयोग किया। इन जहाज़ों के बारे में मैं तुम्हें बाद में बताऊँगा। इन जहाजों ने भारतीय तटीय स्थान पर एक उचित स्थान की खोज की जिसमें पर्याप्त मात्रा में अधिक गुणवत्ता वाले प्लेसर खनिज प्राप्त हुए। भारत के पश्चिम तटीय स्थानों तथा पूर्वी तटीय स्थानों में भी प्लेसर खनिज

चित्र 25 : गवेषणी

मिल रहे हैं। ये विशेष रूप से महाराष्ट्र के रत्नगिरि (Ratnagiri) से, उड़ीसा के दक्षिण भाग जैसे गोपालपुर तथा आन्ध्रप्रदेश के कलिंगापत्तनम क्षेत्र में मिलते हैं।''

"इससे पहले कि आप आगे विवरण दें,'' रामू ने बीच में पूछा, "कृपया मुझे बताइये कि प्लेसर खनिज इतने महत्वपूर्ण क्यों है?''

"ओह हाँ,'' भू-वैज्ञानिक ने उत्तर दिया, "इल्मेनाइट टाइटेनियम ऑक्साइड है। टाइटेनियम वर्णक (Pigment) तथा कठोर और प्रति संक्षारण (Anti Corrogne) ढाँचे के लिए महत्वपूर्ण है। जैसे गहराई में गोता लगाने वाले पोत का ढांचा टाइटेनियम द्वारा तैयार होता है जो समुद्र के नीचे अधिक दबाव सह सकता है। रूटाइल एक दूसरा प्लेसर पदार्थ है, इसमें भी टाइटेनियम होता है। मोनाजाइट एक बहुत महत्वपूर्ण प्लेसर खनिज है जिसमें थोरियम जैसे रेडियोऐक्टिव पदार्थ उपस्थित रहते हैं। थोरियम **नाभिकीय ऊर्जा** (Nuclear Energy) के बनाने में प्रयुक्त होता है।

फॉस्फोराइट निक्षेप (PHOSPHORITE DEPOSITS)

प्लेसर खनिजों के साथ फॉस्फोराइट निक्षेप भारत के अपतट इलाकों के कई स्थानों में पाए जाते हैं। यद्यपि फॉस्फोराइट का समुद्र जल से व्यावसायिक रूप से उत्पादन अभी तक नहीं किया गया है फिर भी वैज्ञानिकों का विश्वास है कि एक दिन समुद्र जल विश्व के उर्वरक की बढ़ती मांग की पूर्ति का एक संसाधन होगा। फॉस्फोराइट निक्षेप प्रधानत: फास्फेट से बना हुआ होता है और यह पर्पटी ग्रंन्थिका तथा रेत के रूप में प्राप्त किया जाता है। वर्तमान समय में भारत बड़ी मात्रा में फॉस्फोराइट आयात कर रहा है। यदि वह चाहे तो कुछ मात्रा में अपने नजदीकी समुद्री क्षेत्रों से अपनी आवश्यकता के लिए फॉस्फोराइट का उत्पादन कर सकता है। पश्चिमी समुद्री तट के सर्वेक्षण के बाद वहाँ कुछ क्षेत्रों में फॉस्फोराइट चट्टानें देखी गयी हैं।''

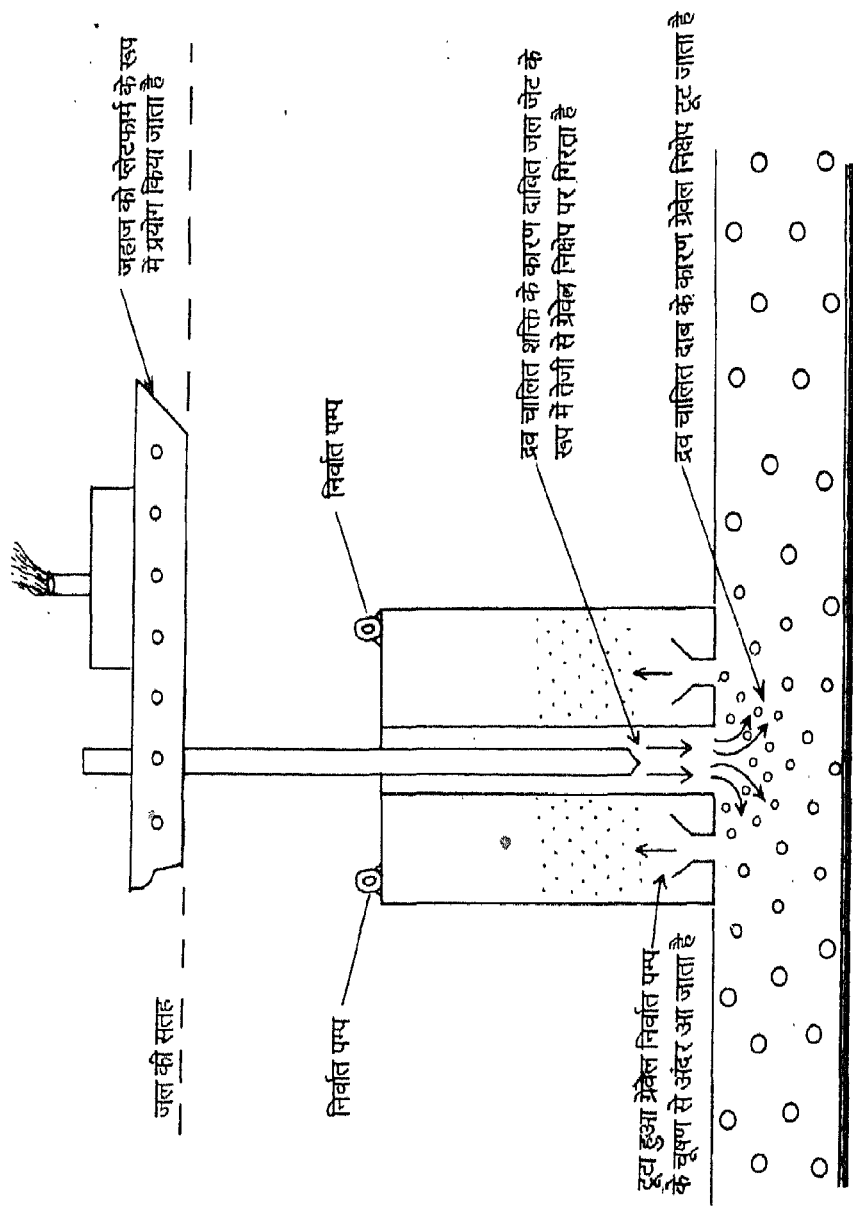
ऐसे समय में रामू ने फिर पूछा, "क्या आप मुझे इस विषय में कुछ ज्ञान दे सकते हैं कि समुद्र तली से विभिन्न प्रकार के खनिज कैसे प्राप्त हो सकते हैं?''

"यह एक अच्छा प्रश्न है,'' भू-वैज्ञानिक ने उत्तर दिया–"समुद्र तली से खनिजों की प्राप्ति के लिए खनन कार्य तीन विधियों द्वारा किया जाता है–**सुरंगन**

(Tunnelling), **पम्पन** (Pumping) तथा **तलमर्जन** (Dredging)। कई कम्पनियाँ समुद्र तली में पाँच किलोमीटर से भी अधिक गहरा गढ्ढा खोदकर कोयला निकालती हैं। समुद्र तली के नीचे से सुरंगन प्रक्रिया द्वारा लोह-अयस्क भी निकाला जाता है। समुद्र तली में सुरंग बनाना बहुत ही खर्चीला तथा जोखिम भरा काम है। सल्फर तथा पोटाश प्राप्त करने के लिए समुद्र तली से खनिज का पम्पन किया जाता है। कई अपतट तथा प्लेसर निक्षेपों को समुद्र तली से समुद्र तट पर पम्पन प्रक्रिया द्वारा ले जाते हैं। तलमार्जक का प्रयोग करके भारी खनिज प्रवाल तथा शंक निकालते हैं।''

भू-वैज्ञानिक यहीं पर रुक गया। रामू की दिलचस्पी अब और भी अधिक बढ़ती जा रही थी, उसने कहा, "मैंने समुद्र से पाये जाने वाली बहुमूल्य धातुओं के विषय में भी सुना है। क्या आप मुझे उन कीमती धातुओं के विषय में कुछ और बतायेंगे?''

भू-वैज्ञानिक ने कहा, "कीमती धातुएँ जैसे सोना तथा प्लैटिनम भी समुद्र से प्राप्त किये जा सकते हैं। यहाँ तक कि हीरा भी समुद्र से प्राप्त किया जा सकता है। एक समय दक्षिण-पश्चिम अफ्रीका (नामिबिया) के अपतट के ग्रैवेल (बजरी) प्लेसर से बहुत अच्छे प्रकार के हीरों का संभरण हुआ करता था। विशेष रूप से सन् 1961-1971 में **मैरिन डायमण्ड कारपोरेशन** ने अभियान के पश्चात् समृद्ध वेदिका तथा उन्नत तटों जैसे स्थानों में से हीरों की खान निकाली। साठ के दशक में इस संस्था ने तीन खनन जहाज़, ग्यारह सहायक जहाज तथा दो हवाई जहाज़ भेजे जिन्होंने **होटेनटोट खाड़ी** (Hottetott Bay) क्षेत्रों में वार्षिक 10 करोड़ रुपये के हीरे प्लेसर ग्रैवेल से प्राप्त किए। ये अधिकांश हीरे **रत्न पत्थर** (Gems Stone) थे। प्लेसर ग्रैवेल द्रवचालित दाब (Hydraulic Pressure) से निकाला जाता है (चित्र 26)।

सोने जैसी कीमती धातु समुद्र से प्राप्त करना बहुत कठिन कार्य है। समुद्र ज़ल में सोना बहुत अल्प मात्रा में घुली हुई स्थिति में होता है। इसकी प्राप्ति आर्थिक दृष्टि से लाभकारी नहीं है। यह गणना की गयी है कि यदि समुद्र तली के एक घन मीटर तलछट (Sediments) में से 15 रु. का सोना प्राप्त किया जा सके, तभी समुद्र तली से सोना निकालने से कुछ लाभ हो सकता है। यह निर्णय लगभग 17-18 वर्ष पहले किया गया था जबकि सोने के मूल्य में तब से अब तक बहुत

चित्र 26 : प्लेसर ग्रैवेल द्रवचालित शक्ति से निकाला जाता है।

अधिक वृद्धि हो गई है। फिर भी समुद्र से सोना प्राप्त करने की विविध विधियों का अनुसंधान किया जा रहा है।

सन् 1960 में **लाल सागर** (Red Sea) के बीच में बहुधात्विक सल्फाइड तलछट पाये गये। इस तलछट की मोटाई 20 मीटर से 100 मीटर तक होती है। 2 से 2.5 किलोमीटर की गहराई तक ये तलछट मिलते हैं। तलछट के ऊपरी भाग का संघटन इस प्रकार है–

लोहा-29%, जिंक- 3.4%, तांबा- 1.3%, सीसा-0.1%, चाँदी-0.005%, सोना- 0.00005%।

समुद्र तली में तलमार्जन करते समय तेज हवा, समुद्री धारा आदि का सामना करना पड़ता है। समुद्री संक्षारण का प्रभाव भी खतरनाक हो सकता है। इन सबको ध्यान में रखते हुए एक उन्नत प्रणाली से विशिष्ट रूप का ड्रेज तैयार किया जाता है। इसमें समुद्र तली पर बहती हुई धारा और गुरूत्व का सहारा लेकर, सोना और भारी धातुओं को अलग किया जाता है। यह तकनीक बहुत ही खर्चीली है– लेकिन समुद्र के पानी में से स्वर्ण निकर्षण के लिए प्रयत्न अभी भी जारी हैं। भू-वैज्ञानिक का यह विश्वास है कि भविष्य में अमरीका के पश्चिमी तट अलास्का, फिलीपाइन एवं सम्भवत: सोवियत फॉर ईस्ट के समुद्री तलछट से सोना प्राप्त करने के कार्य को और प्रोत्साहन दिया जायेगा। अलास्का के अपतट पर **प्लेटिनम प्लेसर** (Platinum Placers) पाये गये हैं। प्लेटिनम सोने से भी ज्यादा कीमती धातु है।'

अध्याय 7

बहुधात्विक पिंडिका और बहुधात्विक सल्फाइड्स

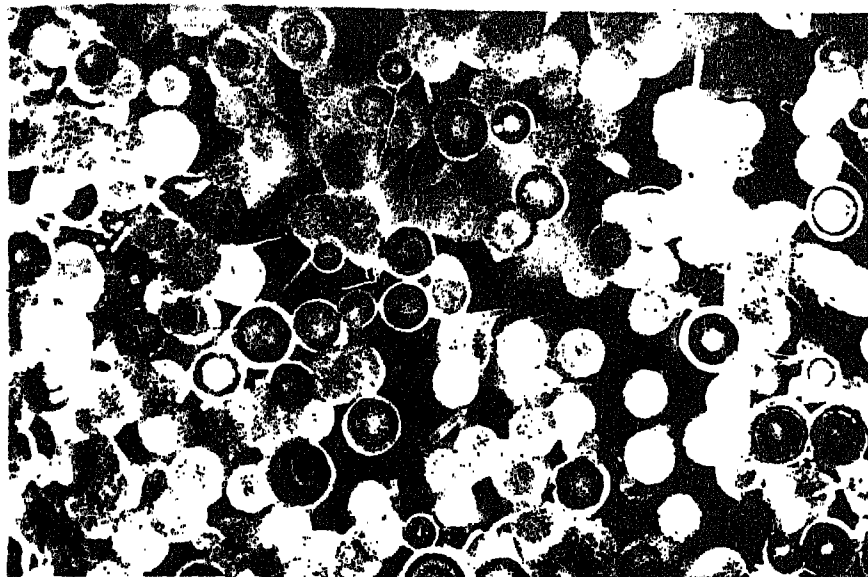
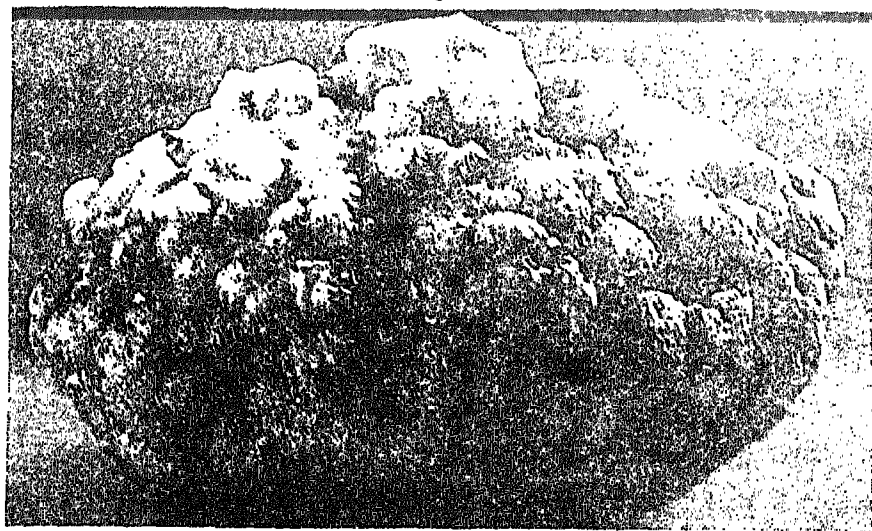
(POLYMETALLIC NODULES AND POLYMETALLIC SULPHIDES)

"तुम्हें शायद ज्ञान नहीं है," भू-वैज्ञानिक ने कहा, "हाल ही में भारत ने गहरे समुद्र के अभियान में एक अद्वितीय स्थान प्राप्त किया है।"

"वह क्या विषय है?" बड़े कौतूहल से रामू ने पूछा।

भू-वैज्ञानिक आगे बढ़ा, "17 अगस्त, 1987 में भारत को गहरे समुद्र हिन्द महासागर में खान क्षेत्र दिया गया।"

"गहरे सागर में खान का क्षेत्र!" रामू ने आश्चर्य से पूछा।

"हाँ यह एक ऐसा ही विषय है। मुझे इस विषय में विस्तृत विवरण देने दो। महासागर की गहरी तली में आलू की शक्ल की बहुधात्विक पिंडिकाएँ (Polymetallic Nodules) पाई जाती हैं। इनके आकार में परिवर्तन होते रहते हैं। ये कई 1 सेंन्टीमीटर व्यास की होती हैं तो कई बहुत विशाल 25 सेंन्टीमीटर व्यास की। ये गहरे भूरे रंग से काले रंग में परिवर्तित होती रहती हैं। ये आमतौर से वजन में हल्की होती हैं परन्तु फिर भी पानी से कई गुना भारी तथा सूक्ष्म होती हैं (चित्र-27)। ये प्याज की भाँति महीन लेकिन दृढ़ पर्तों में दिखाई देती हैं। पिंडिका के केन्द्र में नाभिक होता है। कभी-कभी एक अन्य नाभिक पहले नाभिक की वृद्धि के चारों ओर एकत्रित होता है (चित्र-28)। नाभिक मिट्टी का कण, शार्क के दांत का टुकड़ा या जीवाणु जैसा पदार्थ हो सकता है जिसमें परतें बनती हैं। नाभिक में करीब सभी पदार्थ, विशिष्ट धातुओं-जैसे-तांबा, निकेल, कोबाल्ट,

चित्र 27 : बहुधात्विक पिडिंका

चित्र 28 : बहुधात्विक पिडिंका के एक अंश का आवर्धित रूप।

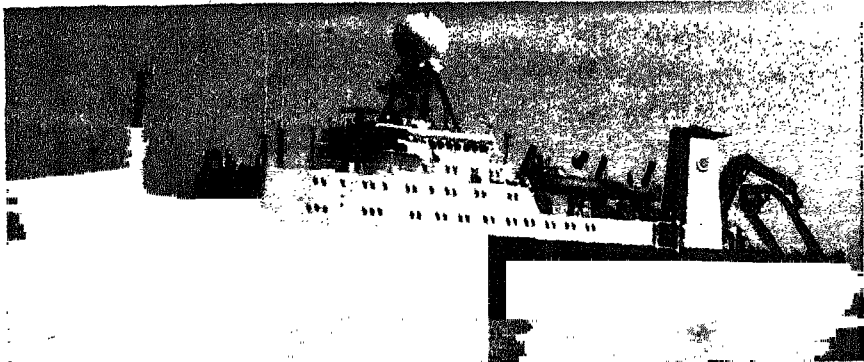
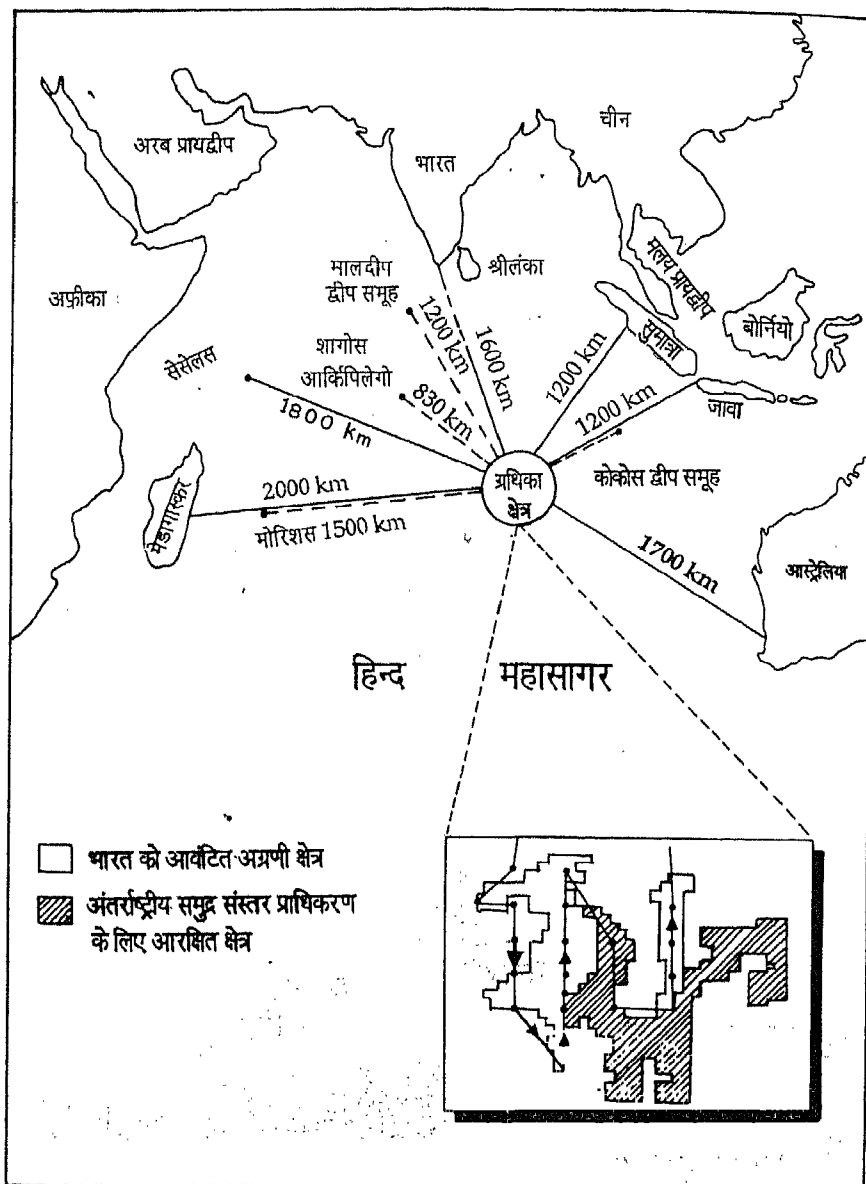
मैंगनीज, तथा लोहा के साधारण ऑक्साइड या हाइड्रोऑक्साइड होते हैं। मैंगनीज तथा लोहा इनमें प्रधान धातुएँ हैं। इसके साथ-साथ थोड़ी मात्रा में आक्साइड तथा हाइड्रोऑक्साइड के रूप में भिन्न धातुएँ जैसे कैडमियम, जिंक, लेड (सीसा), क्रोमियम, तांबा, कोबाल्ट, निकेल, टाइटेनियम इत्यादि पायी जाती हैं। तांबा, कोबाल्ट तथा निकल की बहुत मांग है। हम भारतवर्ष में 65% तांबा आयात करते हैं, जबकि निकेल तथा कोबाल्ट पूरा का पूरा आयात किया जाता है। जैसा कि तुम जानते हो कि ताँबे से बिजली के तार बनाए जाते हैं, तथा यह कीमती मिश्र धातु जैसे पीतल तथा कांसा बनाने के काम में भी आता है। ताँबा बर्तन बनाने के काम आता है क्योंकि तांबा-अग्नि तथा बिजली दोनों के लिए उपयुक्त चालक है। निकेल प्रति संक्षारण गुण के लिये प्रयोग में लाया जाता है। यह सम्पूर्ण रूप से निकेल प्लेटिंग तथा हाइड्रोजोनीकरण के लिए **उत्प्रेरक** (Catalyst) के रूप में प्रयोग किया जाता है। निकेल से प्राप्त मिश्र धातुएँ (Alloys) उद्योगों में विशेष रूप से प्रयोग की जाती हैं। निकेल मिश्र धातु जैसे **निक्रोम** (Nichrome) ताप प्रतिरोधक के रूप में कार्य करता है। निकेल और एक मिश्र धातु जर्मन सिलवर कटलरी के बनाने के काम में लाया जाता है। कोबाल्ट संक्षरण प्रतिरोधी मिश्र धातु एवं चुम्बकों के बनाने में काम में लाया जाता है।''

यहाँ पर रामू बीच में बोल उठा और पूछा, ''कृपया मुझे बताइये कि समुद्र से पिंडिकाओं को कैसे निकाला जाता है तथा पिंडिकाओं से धातुएँ किस प्रकार प्राप्त की जाती हैं?''

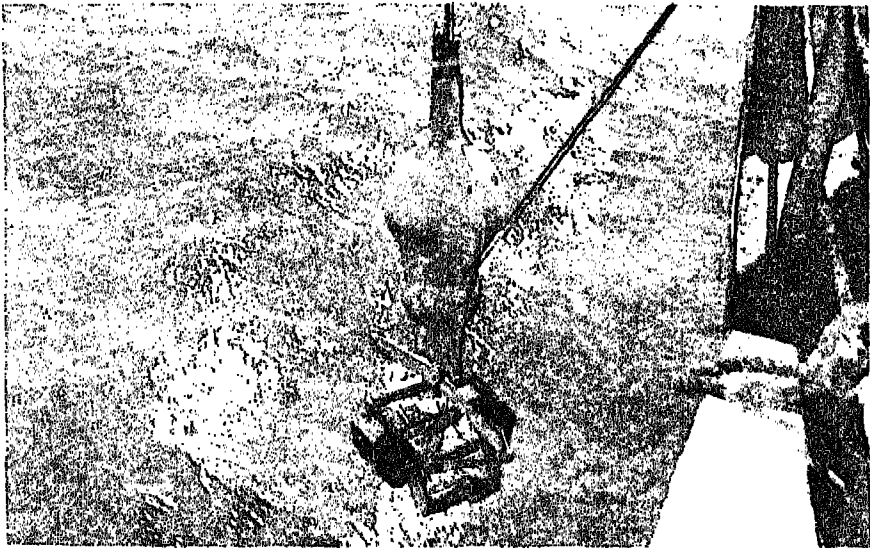
''मैं तुम्हारी रुचि को देखकर बहुत प्रसन्न हुआ'', भू-वैज्ञानिक ने उत्तर दिया और आगे विवरण दिया।

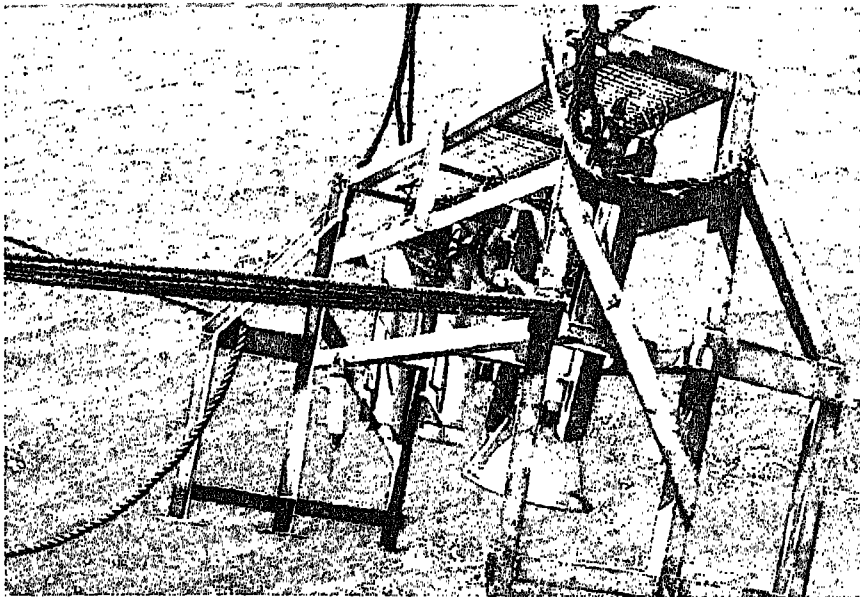
''मैंगनीज पिंडिकाएँ समुद्र तली के कई स्थानों में पाई जाती हैं। ये समुद्र तली में 3.5 से 6 किलोमीटर की गहराई तक पायी जाती हैं। अनुमान है कि हिन्द महासागर में ये 100 से 150 लाख वर्ग किलोमीटर स्थान में फैली हुई हैं। यदि तुम पिंडिका प्राप्ति का समस्त सागर तली में अनुमान लगाओ तो ये कुल मिलाकर 460 लाख वर्ग किलोमीटर स्थान में फैली हुई हैं। प्रथम पिंडिका प्रतिदर्श 26 जनवरी, 1981 में **राष्ट्रीय समुद्र विज्ञान संस्थान** (नेशनल इन्स्टीट्यूट ऑफ ओसनोग्राफी) के वैज्ञानिकों

द्वार। एकत्रित किया गया था। राष्ट्रीय समुद्र विज्ञान संस्थान समुद्र विज्ञान के क्षेत्र में एक अन्तर्राष्ट्रीय प्रसिद्धि प्राप्त वैज्ञानिक संस्था है। डॉ. एस. जैड. कासिम जो उस समय संस्था के निदेशक थे और प्रथम पिंडिका प्रतिदर्श उठाने वाले इस दल के नेता भी थे। उसके पश्चात् कुछ किलोग्राम पिंडिकाएँ एकत्रित की गई। इस दल ने **गवेषणी** नामक परिष्कृत समुद्र वैज्ञानिक अनुसंधान जलयान का प्रयोग किया (चित्र-25)। तुम्हें मैं अब कुछ समय पश्चात् इस जहाज के विषय में बताऊँगा। प्रारम्भ से ही यह जहाज़ पिंडिकाओं के लिए सर्वेक्षण तथा अन्वेषण का कार्य कर रहा है। इस क्षेत्र में एक दूसरा समुद्री वैज्ञानिक अनुसंधान जहाज **'सागर कन्या'** भी प्रयोग में लाया गया। यह आधुनिकतम यंत्रों से सुसज्जित समुद्र में जाने वाला जहाज़ है (चित्र-29)। यह जहाज़ महासागर विकास विभाग का है। इसके साथ विदेशों से किराये पर लिए गए कुछ अनुसंधान जहाज़ जैसे **स्कन्डी सर्वेयर** (नार्वे से,) **फार्नेला** (इग्लैंड से), तथा **जी.ए. रीये** (इंग्लैंड से) भी थे। एक देशी जहाज़ भी जिसका नाम है **"नन्दरचित"** किराये पर लिया गया था।

हिन्द महासागर के मध्य में 40 लाख वर्ग किलोमीटर स्थान का सर्वेक्षण तथा अनुसंधान करने के पश्चात् भारत ने दो खान स्थलों का पता लगाया। प्रत्येक स्थल 150.000 वर्ग किलोमीटर स्थान घेरते हैं। इनमें से एक स्थल भारत को भविष्य में बहुधात्विक पिंडिका के खनन के लिए दिया गया है (चित्र-30)। यह खनन स्थल पिंडिकाओं से भरपूर है जिसका प्रयोग हम कई दशकों तक कर सकते हैं। यह खान

चित्र 29 : सागर कन्या

चित्र 30 : बहुधात्विक पिंडिकाओं का खननस्थल

जैसा कि तुम नक्शे में देखोगे, कन्याकुमारी के दक्षिण में 1600 किलोमीटर से भी अधिक दूरी पर है (चित्र-30)।''

रामू ने पूछा, "क्या आप मुझे बता सकते हैं कि किस प्रकार इन पिंडिकाओं को समुद्र से उठाया जाता है तथा कैसे इनको रखा जाता है? मैं समझता हूँ कि 3.5 से 6 किलोमीटर तक की गहराई से इनको समुद्र तली से एकत्रित करना बहुत ही खर्चीला होगा।'' "हाँ तुम ठीक कहते हो'', भू-वैज्ञानिक ने उत्तर दिया। "अभी तक पिंडिका को **बुमारंग ग्रेब** (Boomerang Grab) तथा ड्रेज (Dredge) की सहायता से एकत्रित किया जाता है (चित्र 31-32)। ड्रेज द्वारा हम एक बार में 20-30 किलोग्राम पिंडिकाएँ एकत्रित कर उठा सकते हैं। ड्रेज पानी में मजबूत इस्पात तार की सहायता से डुबाया जाता है। जब यह समुद्र तली को स्पर्श कर लेता है तब कई सौ मीटर तक इसको खींचा जाता है। इस विधि द्वारा समुद्र तल से पिंडिकाओं को निकाला जाता है। जब पिंडिकाओं का निकर्षक (ड्रेज) *लगभग भर जाता है तो* इसका *ढक्कन* अपने आप ही बन्द हो जाता है और यह ऊपर उठा लिया जाता है।''

चित्र 31 : बुमारग ग्रैब जहाज की ड्रेक से समुद्री जल के अन्दर भेजा जा रहा है। नीचे एक कैमरा भी संलग्न है जिससे समुद्र की तली के चित्र लिए जा सकते हैं *(एन.आई.ओ. के सौजन्य से)*

चित्र 32 : ड्रेज– समुद्रतली से एक ड्रेज को जहाज़ के डेक पर उठा लिया गया। ड्रेज से बहुधात्विक पिंडिकाओं को निकाला जाता है। *(एन.आई.ओ. के सौजन्य से)*

चित्र 33 : अंतर्जलीय फोटोग्राफी के लिए फोटोस्लेज कैमरा। *(एन.आई.ओ. गोवा के सौजन्य से)*

रामू ने पूछा, "समुद्रतली की फोटो कैसे खींची जाती है?"

भू-वैज्ञानिक ने कहा, "इसके लिए फोटोस्लेज कैमरा होता है (चित्र-33)। अधिक मात्रा में 20-30 टन प्रति घंटे की क्षमता से पिंडिकाओं को उठाने की दक्षतापूर्ण विधि पर लगातार अनुसंधान कार्य चल रहा है। इस विषय में तीन विधियों का प्रयोग किया जा रहा है–

(क) **जलीय उत्थापन प्राणाली** (Hydraulic System)

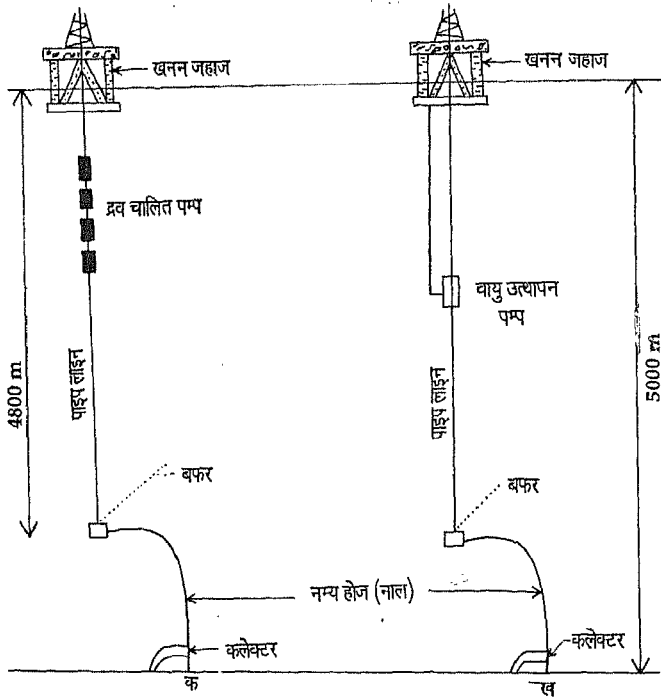
(ख) **वायु उत्थापन प्रणाली** (Air Lift System)

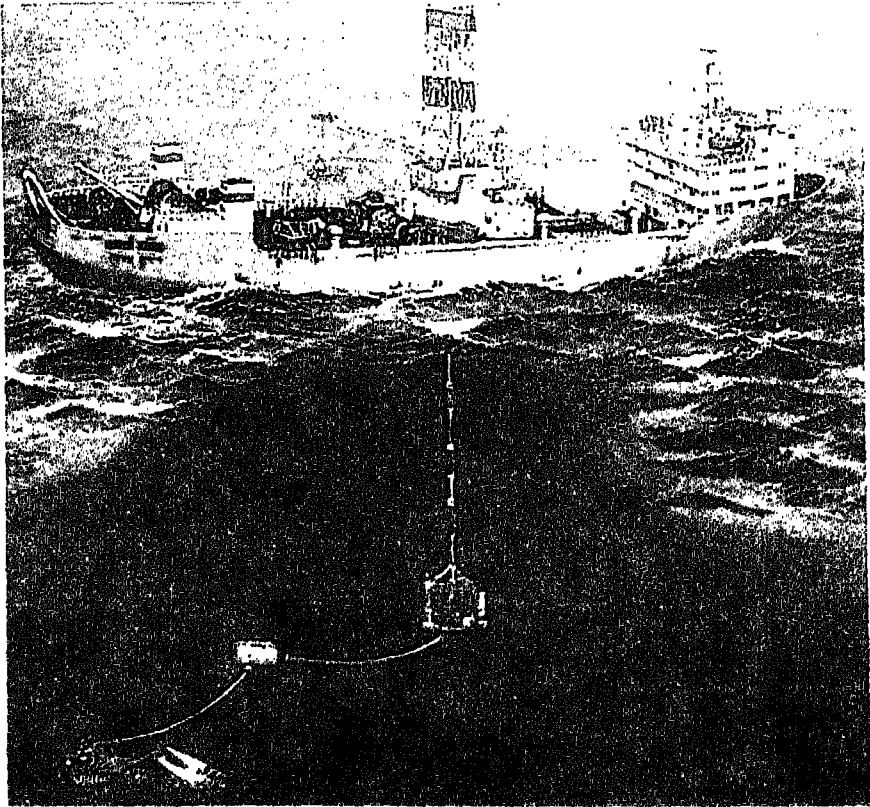
(ग) **सतत लाइन बकेट प्रणाली** (Continuous Line Bucket System)

चित्र 34 में जलीय उत्थापन प्रणाली और वायु उत्थापन प्रणाली के सम्बन्ध में एक रेखाचित्र प्रस्तुत किया गया है। चित्र-35 में गंभीर समुद्र तली से बहुधात्विक पिंडिका की खनन कार्य प्रणाली दिखायी गयी है। चित्र-36 में देखा जा सकता है कि कलेक्टर

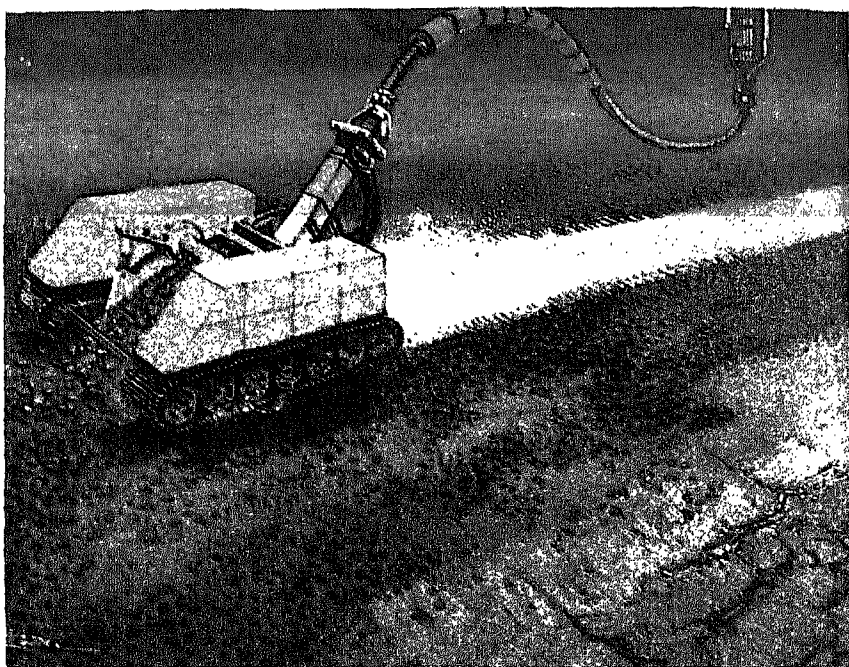
कैसे समुद्र तली से बहुधात्विक पिंडिका उठा लेता है। चित्र-37 में सतत लाइन बकेट प्रणाली का एक रेखाचित्र प्रस्तुत किया गया है।

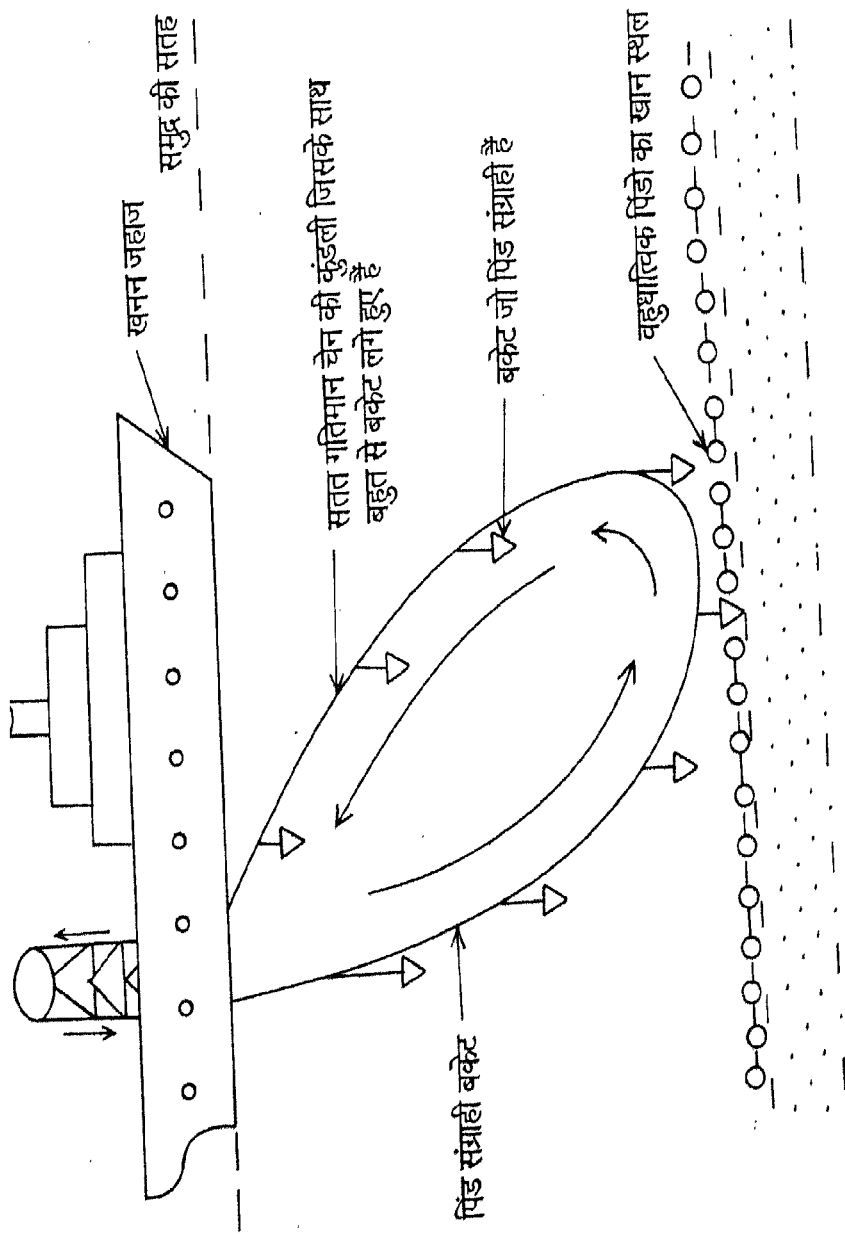
यद्यपि गहरे समुद्र में पिंडिकाओं के खनन के बारे में अनुसंधान कार्य चल रहे हैं। इससे पहले कि हम व्यावसायिक मात्रा में खनन की कोई संतोषप्रद तकनीक को जान सकें कम से कम एक दशक या उससे अधिक समय लगेगा। साथ-साथ हमें यह भी सुनिश्चित करना होगा कि समुद्र तली में अधिक मात्रा में खनन करने से सामुद्रिक वातावरण को कोई क्षति तो नहीं पहुँचेगी।

समुद्र तली से पिंडों का खनन करने में अनेक समस्याएँ हैं जिनका सावधानीपूर्वक मूल्यांकन किया जाना चाहिए। बड़े पैमाने पर किये जाने वाले ख़नन कार्य के दौरान

चित्र 34 क : जलीय उत्थापन प्रणाली

चित्र 34 ख : वायु उत्थापन प्रणाली

चित्र 35 : समुद्रतली से बहुधात्विक पिंडिकाओं की खनन कार्य प्रणाली

अपार जलराशि के विकृत होने की अनेक सम्भावनाएँ बनी रहती हैं जिसके कारण समुद्र तल के तलछट में उत्तेजना एवं विक्षोभ आ सकते हैं। यह अनुभव किया जाता है कि वह स्थिर समुद्र तली, जो लाखों वर्षों से है, उसके उत्तेजित हो जाने से खनन द्वारा पिंडों के उत्पादन में पूर्णतया कमी आ सकती है। इससे समुद्र तली में नितलस्थ जीव (Benthic Animals) भी नष्ट हो सकते हैं।''

अब रामू ने पूछा, ''कृपया मुझे यह बताइये कि तांबा, निकेल तथा कोबाल्ट जैसी धातुएँ बहुधात्विक पिंडिकाओं से कैसे प्राप्त की जाती है?''

चित्र 36 : समुद्रतली में कार्य करता कलेक्टर

भू-वैज्ञानिक ने उत्तर दिया– "धातुओं का पिंडिका से निष्कर्षण **'निष्कर्षण धातु कर्म'** (Extractive Metallurgy) नाम से जाना जाता है। कई रासायनिक तत्वों की विधि के प्रयोग द्वारा तथा तापमान और दबाव की उपयुक्त परिस्थिति से ही धातुओं को पिंडिकाओं से अलग किया जाता है। इस कार्य के लिए सल्फर-डाई-ऑक्साइड और अमोनिया या सल्फ्यूरिक ऐसिड प्रयोग में लाया जाता है। पिंडिका से धातुकर्म बहुत जटिल विधि है। वर्तमान समय में भारत में चार प्रयोगशालाएँ इस विषय में व्यस्त रूप से कार्य कर रही हैं, वे हैं–भुवनेश्वर में रीजनल रिसर्च लैबोरेटरी (Regional Research Laboratory), जमशेदपुर में नेशनल मेटालर्जिकल लैबोरेटरी (National Metallurgical Laboratory), उदयपुर में हिन्दुस्तान जिंक लिमिटेड (Hindusthan Zinc Limited) तथा खेत्री में हिन्दुस्तान कॉपर लिमिटेड (Hindustan Copper Limited)। इससे पहले कि मैं और भी विवरण दूँ मैं तुम्हें यह बताना पसन्द करूंगा

चित्र 37 : सतत लाइन वकेट प्रणाली

कि बहुधात्विक पिंडिका के सक्रिय वैज्ञानिक कार्यक्रम में भारत ने सर्वोपरि मान्यता प्राप्त की है। भारतवर्ष संसार के छः देशों में एक है जिसने समुद्र के क्षेत्र में **अग्रणी निवेशक** (REGISTERED PIONEER INVESTOR) की मान्यता प्राप्त की है। शेष पाँच देश हैं– फ्रांस, जापान, सोवियत रूस, चीन तथा दक्षिण कोरिया।

जैसे कि पहले ही मैंने बताया समुद्र तली के खनन में नवीन कार्य के क्षेत्र में भारत विश्व में पहला देश है जिसे संयुक्त राष्ट्र से खान क्षेत्र प्राप्त हुआ है। यह महत्वपूर्ण उपलब्धि 17 अगस्त, 1987 को प्राप्त हुई थी, खासकर ऐसे सुनहले मौके पर जब हम आजादी की 40वीं वर्षगांठ मना रहे थे। इस उन्नतिपूर्ण वैज्ञानिक कार्य का समस्त श्रेय हमारे वैज्ञानिकों को दिया जाना चाहिए।

बहुधात्विक सल्फाइडस

बहुधात्विक पिंडिका के अलावा बहुधात्विक सल्फाइडस(Polymetallic Sulphides) निक्षेप भी गहरी समुद्र तली में पाये जाते हैं। उसमें अधिकतम मात्रा में तांबा, जिंक तथा लोहे का अंतर्विष्ट सांद्रण होता है। किन्तु बहुधात्विक पिंडिकाओं की तुलना में सल्फाइड निक्षेपों में दूसरे तत्वों का सांद्रण कम होता है। इसके साथ ही पिंडिकाओं की तुलना में सल्फाइड बहुत कठोर होते हैं। इन सल्फाइड निक्षेपों को विशिष्ट विद्युत चालित ग्रैब द्वारा एकत्रित किया जाता है। इस ग्रैब के साथ एक अंतर्जलीय दूरदर्शन कैमरा (Underwater TV Camera) संलग्न होता है। ग्रेब के जबड़े में बहुत सूक्ष्म काटने वाला किनारा होता है। जबड़े **सुदूर नियंत्रण** (Remote Control) द्वारा खुलते और बन्द होते हैं। जब यह जबड़ा बंद होता है तो यह सल्फाइड निक्षेप को अन्दर उठाता है।

अन्त में मैं तुम्हें यह अवश्य बताऊँगा कि भविष्य में प्रौद्योगिकी में और भी विकास होने पर बहुधात्विक पिंडिकाओं तथा सल्फाइड निक्षेपों को विस्तृत पैमाने पर उपयोग में लाया जा सकता है। इस क्षेत्र में हमें अभी बहुत उन्नति करनी है तथा व्यापारिक रूप से इनकी प्राप्ति सन् 2000 ई. से पहले संभव नहीं है किन्तु इनके सफल परिणाम की संभावना बहुत ही उच्च है।''

अध्याय 8

समुद्र विज्ञान संबंधी प्रौद्योगिकी

(MARINE SCIENCE TECHNOLOGY)

"अभी तक आप सामुद्रिक अभियान, सर्वेक्षण, अन्वेषण तथा सागर की सम्पदा के विषय में विवरण दे रहे थे," रामू ने कहा। "कृपया आप मुझे इस उद्देश्य के लिए व्यवहार में लाये जाने वाले सामुद्रिक जहाज के विषय में कुछ बताइये।"

भू-वैज्ञानिक ने कहना प्रारम्भ किया- "कई समुद्र वैज्ञानिक अनुसंधान जहाज़ हैं जो आधुनिक यंत्रों से सुसज्जित हैं। ये यंत्र हमें तापमान, समुद्री जल में लवण की मात्रा, समुद्र की गहराई, समुद्र सतह की प्रकृति, समुद्र तली पर तलछट की प्रकृति, समुद्रतली में चट्टान तथा खनिज की प्रकृति इत्यादि के विषय में ज्ञान देने में सहायता करते हैं। कुछ यंत्र समुद्रतली में जीवित प्राणियों की स्थिर तथा वीडियो तस्वीरें लेते हैं तथा कुछ चट्टानों तथा खनिजों की तस्वीरें भी लेते हैं। जहाज़ में ऐसे परिशुद्धता से मापने वाले यंत्र (Precision Equipment) होते हैं जो जहाज़ की तट से दूरी तथा उसकी सही स्थिति को सूचित करते हैं। पृथ्वी के उस अनुसंधान केन्द्र के साथ एक नियमित संचार व्यवस्था स्थापित रहती है जो जहाज़ को समुद्र में भेजता है। इसके अतिरिक्त यह जहाज़ अन्य विख्यात अनुसंधान केन्द्रों से भी संचार सम्पर्क स्थापित कर सकता है। समुद्र वैज्ञानिक अनुसंधान जहाजों में से कुछ के नाम पृष्ठ संख्या 92 में दिये गये हैं–

अनुसंधान जहाज़	*संबंधित राष्ट्र*	*अनुसंधान जहाज़*	*संबंधित राष्ट्र*
सर्वेयर	यू.एस.ए.	**चार्लस कोनराड**	यू.एस.ए.
टांमस कुक	आस्ट्रेलिया	**ग्लोमर चैलेन्जर**	यू.एस.ए.
जीन चारकोट	फ्रांस	**चार्ल्स डार्विन**	यू.के.
सोने	जर्मनी	**सागर कन्या**	भारतवर्ष
पोलर स्टारन	जर्मनी	**सागर सम्पदा**	भारतवर्ष
मीटिअर 1 और 2	जर्मनी	**गवेषणी**	भारतवर्ष
अटलांटिस 2	यू.एस.ए.	**समुद्र मंथन**	भारतवर्ष

अब मैं तुम्हें भारत में उपलब्ध समुद्र वैज्ञानिक अनुसंधान जहाज़ों के विषय में कुछ बताऊँगा। दिल्ली में स्थित **'महासागर विकास विभाग'** जो भारत सरकार के अधीन एक विशिष्ट मंत्रालय है वह सामुद्रिक विकास के विस्तृत कार्यक्रमों में महत्वपूर्ण भूमिका निभाता है। इसके दो सुसज्जित समुद्र वैज्ञानिक अनुसंधान जहाज़ हैं– **सागर कन्या** तथा **सागर सम्पदा।**

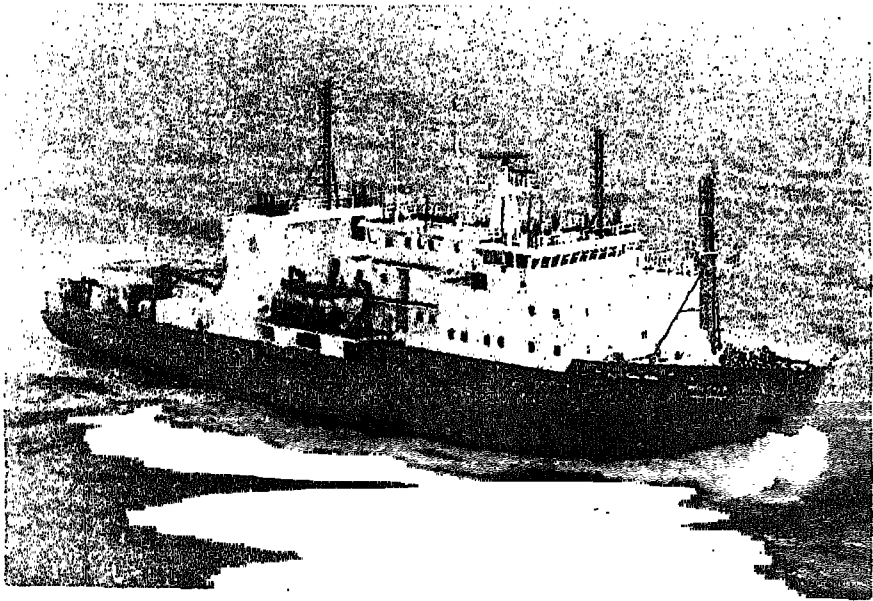
सागर कन्या : 18 मार्च, 1983 को महासागर विकास विभाग ने यह अनुसंधान पोत प्राप्त किया (चित्र-29)। इसका डिजाइन तथा निर्माण जर्मनी में किया गया था। यह पोत संसार का एक परिष्कृत रूप से सुसज्जित तथा उच्च स्तर का समुद्र वैज्ञानिक अनुसंधान जहाज़ है। यह समुद्र में 45 दिन तक बिना किसी बंदरगाह पर रुके सफर कर सकता है। इस जहाज में नाविकों तथा वैज्ञानिकों के लिए पर्याप्त मात्रा में पीने का पानी तथा भोजन और जहाज़ को चलाने के लिए कम से कम 45 दिन का पर्याप्त मात्रा में ईंधन रहता है। कोई जहाज समुद्र में जितने दिन तक रह सकता है वह उसकी क्षमता (Endurance) कहलाती है। इस अवधि में जहाज यदि समुद्र में बिना रुके चले तो वह 15000 किलोमीटर तक की यात्रा कर सकता है। **सागर कन्या** के अन्तर्गत चार मोटर चालित तंतुक शीशों (Fibre Glass) की नौकाएँ होती हैं जो संकट के समय लोगों के जीवन को बचाने के लिए सक्षम हैं। इसके सभी यंत्र कम्प्यूटरीकृत हैं। इसकी लम्बाई 100.34 मीटर, चौडाई 16.39 मीटर तथा

अधिकतम गति सीमा 14.25 समुद्री मील (Knots) है। (अर्थात् 25 किलोमीटर प्रति घंटे के लगभग)। इसमें 91 व्यक्ति एक साथ रह सकते हैं जिनमें 59 जहाज़ के अफ़सर तथा नाविक, 23 वैज्ञानिक, एक डाक्टर और 8 तकनीशियन हैं। जहाज़ में दो रसोईघर हैं। तीन खाना खाने के कमरे और एक सम्मेलन कक्ष है। मनोरंजन के लिए इसमें तीन कमरे हैं। इनमें सात टी.बी. सेट्स, एक विडियो रेकार्डर इत्यादि हैं। इसमें 13 प्रयोगशालाएँ हैं जो समुद्र वैज्ञानिक अनुसंधान कार्यों के लिए विभिन्न आधुनिक यंत्रों से सुसज्जित हैं। अभी तक इस जहाज ने कई महत्वपूर्ण यात्राएँ की हैं।

जैसेकि मैंने अभी बताया कि इस जलयान में 13 प्रयोगशालाएँ हैं। वे भू-विज्ञान, भू-भौतिकी, मौसम विज्ञान, रसायन समुद्र विज्ञान, भौतिक समुद्र विज्ञान, तथा समुद्र जैविकी में समुद्र वैज्ञानिक अनुसंधान के लिए आधारभूत उपकरणों से पूर्णतया सुसज्जित हैं। जीव विज्ञान संबंधी कार्य के लिए एक नम प्रयोगशाला (Wet Laboratory) तथा भौतिक समुद्र वैज्ञानिक कार्य के लिए एक शुष्क प्रयोगशाला (Dry Laboratory) की इसमें व्यवस्था की गई है। इसके द्वितीय डैक पर, रासायनिक, भू-भौतिकी तथा बहुप्रयोजनी इलैक्ट्रॉनिक प्रयोगशालाएँ स्थित हैं। फोटो प्रयोगशाला, प्रिंट कक्ष, चार्ट एवं बैठक कक्ष तथा कम्प्यूटर मुख्य कक्ष में होते हैं। सभी प्रयोगशालाएँ वातानुकूलित हैं और इनमें स्वच्छ जल, समुद्र जल, शुद्ध एवं आसवित जल की व्यवस्था है।

समुद्र वैज्ञानिक अनुसंधान जलयान- **सागर कन्या** से 31 वैज्ञानिकों के एक दल ने 3 सितम्बर से 13 सितम्बर, 1987 तक मारीशस में हुए **अन्तर्राष्ट्रीय महासागर उत्सव** में भाग लिया। मारीशस सरकार ने इस अवसर का लाभ उठाते हुए मारीशस के **तटीय जलक्षेत्र** और **अनन्य आर्थिक क्षेत्र** (Exclusive Economic Zone) में जलराशिक सर्वेक्षण (Hydrographic Survey) और बहुआयामी (Multi Disciplinary) समुद्र वैज्ञानिक अध्ययन किये जाने के लिए भारत सरकार से तकनीकी सहायता का अनुरोध किया था। राष्ट्रीय समुद्र विज्ञान संस्थान के वैज्ञानिकों के 7 सदस्यों के एक तटीय दल ने मारीशस के वैज्ञानिकों और अधिकारियों के साथ मिलकर तटीय पर्यावरणीय अध्ययन किए जबकि समुद्र वैज्ञानिक जलयान **सागर कन्या** को 21

भारतीय और 8 मारीशस के वैज्ञानिकों के साथ मारीशस के अनन्य आर्थिक क्षेत्र में एक बहुआयामी समुद्र वैज्ञानिक प्रेक्षण कार्यक्रम में लगाया गया।

सागर सम्पदा : यह बहुमुखीय मात्स्यकी तथा सामुद्रिक अनुसंधान जहाज है, (चित्र-38)। यह जहाज़ डेनमार्क में तैयार किया गया था। यह जहाज़ **महासागर विकास विभाग** को 6 नवम्बर, 1984 में सौंपा गया। इसकी लम्बाई 71.50 मीटर तथा चौड़ाई 16.40 मीटर है तथा अधिकतम गति 23 किलोमीटर प्रति घंटा है। इसमें 59 नाविक तथा वैज्ञानिक एक साथ रह सकते हैं। इसमें कई प्रयोगशालाएँ हैं। इस पोत में सभी प्रकार की सामुद्रिक मछलियों को पकड़ने के विशेष यंत्र हैं। इसके पोतखोल (Hull) की विशिष्ट बनावट होती है। इसलिए यह सुदूर दक्षिण में 60° अक्षांश तक अंटार्कटिक सागर में पायी जाने वाली क्रिल मछलियों को पकड़ने के लिए जा सकता है।

चित्र 38 : सागर सम्पदा'

इस मत्स्य तथा समुद्र वैज्ञानिक अनुसंधान जलयान **'सागर सम्पदा'** के वैज्ञानिक कार्यक्रम का प्रबंध कोचीन स्थित **केन्द्रीय समुद्री मत्स्य अनुसंधान संस्थान** (Central Marine Fisheries Research Institute) द्वारा किया जाता है। इस जलयान की यात्राओं में बहुत से संस्थानों के वैज्ञानिक भाग लेते हैं, जैसे **राष्ट्रीय सुदूर संवेदन एजेंन्सी** (Central Remote Sensing Agency), **भारतीय मत्स्य सर्वेक्षण** (Fisheries Survey of India), **राष्ट्रीय भौतिक और समुद्र वैज्ञानिक प्रयोगशाला** (National Physical and Oceanographic Laborary), **भारतीय कृषि अनुसंधान संस्थान** (Indian Agricultural Research Institute), **केन्द्रीय मत्स्य शिक्षण संस्थान** (Central Institute of Fisheries Education), **केरल विश्वविद्यालय, आन्ध्र विश्वविद्यालय** तथा **अन्नमलाई विश्वविद्यालय** के वैज्ञानिक।

उपरोक्त जहाज़ के साथ-साथ गोवा में स्थित **नेशनल इन्स्टीट्यूट आफ ओसनोग्राफी** के अधीन समुद्री अनुसंधान जहाज़ **'गवेषणी'** भी है (चित्र-25)। यह प्रथम बहुआयामी सामुद्रिक जहाज़ भारत ने सन् 1976 में प्राप्त किया था। इसमें 19 वैज्ञानिक तथा 45 जहाज के अफसर तथा नाविक एक साथ रह सकते हैं। इसकी लम्बाई 68.33 मीटर तथा चौड़ाई 12.19 मीटर और गति सीमा 10 समुद्री मील हैं (चित्र-25)। इसमें चार प्रयोगशालाएँ हैं।

एक और परिष्कृत एवं विकसित समुद्र वैज्ञानिक अनुसंधान जहाज़ **'समुद्र मंथन'** है। यह भारतीग भू-वैज्ञानिक सर्वेक्षण विभाग के अधीन है। इसकी लम्बाई करीब 70 मीटर है। इसमें भी कई प्रयोगशालाएँ हैं।

उपरोक्त **समुद्र वैज्ञानिक अनुसंधान जहाज़** के साथ-साथ कई **तटीय अनुसंधान जहाज़** (Coastal Research Vessel) भी हैं। **भारतीय भू-वैज्ञानिक सर्वेक्षण विभाग** के पास इस प्रकार के दो जहाज़ जैसे **' समुद्र कौसटाव '** तथा **'समुद्र सौधीकामा '** हैं। इस प्रकार के जहाज़ गहरे समुद्र में नहीं जा सकते। समुद्र में इस जहाज़ का स्थायित्व या क्षमता केवल 7 से 10 दिन की होती है। यह सुन्दर यंत्रों से सुसज्जित है। इन जलयानों को समुद्र तट के निकट निर्जीव सम्पदा जैसे चट्टान, तलछट, खनिज इत्यादि के अध्ययन के काम में लाया जाता है।

अध्याय 9

समुद्री जल का विलवणीकरण
(DESALINATION OF SEA WATER)

"अभी तक आप समुद्री जल के निर्जीव पदार्थों तथा सजीव प्राणियों के विषय में बता रहे थे," रामू ने कहा। "इस बात से मैं आश्चर्यचकित हूँ कि यदि पृथ्वी का 70% स्थान जल से घिरा हुआ है तो पीने के जल क; इतना अभाव क्यों है? भारत के कई स्थानों में पीने के पानी की कमी बनी हुई है, क्या हम समुद्र के जल को पीने योग्य नहीं बना सकते?"

"हाँ तुम्हारा प्रश्न काफी तर्कसंगत है", भू-वैज्ञानिक ने सिर हिलाते हुए कहा। "समुद्र के तटवर्ती स्थान जैसे तमिलनाडु, कर्नाटक, उड़ीसा तथा गुजरात में पीने के पानी का अभाव है। कभी अंग्रेज कवि **सैमुएल टेलर कोलरीज** (SAMUEL TAYLOR COLERIDGE) ने कहा था कि "प्रत्येक स्थान पर जल ही जल है परन्तु पीने के लिए एक बूंद भी जल नहीं है।* वास्तव में, समुद्र का जल इतना नमकीन है कि इसे कोई ग्रहण नहीं कर सकता। पेय जल में लवण की मात्रा कम होनी चाहिए। लवण की मात्रा के अनुसार जल को निम्न वर्गों में विभाजित किया जा सकता है।

पेयजल (Potable Water) : जहाँ लवण की मात्रा 500 से 1,000 भाग प्रति मिलियन भाग@ में (अर्थात् लवण की मात्रा 0.05% से 0.1% तक)।

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* इसका अंग्रेजी मूल है "Water, water everywhere but not a drop to drink (Rhyme of the Ancient Mariner)

@ मिलियन (Million) का अर्थ 10 लाख।

खारा जल (Brackish Water) : जहाँ लवण की मात्रा 1000 से 10000 भाग प्रति मिलियन भाग में (अर्थात् लवण की मात्रा उच्चतम 1% तक)।

लवण जल (Saline Water) : जहाँ लवण की मात्रा 10,000 से 30,000 भाग प्रति मिलियन भाग में (अर्थात् लवण की उच्चतम मात्रा 3% तक)।

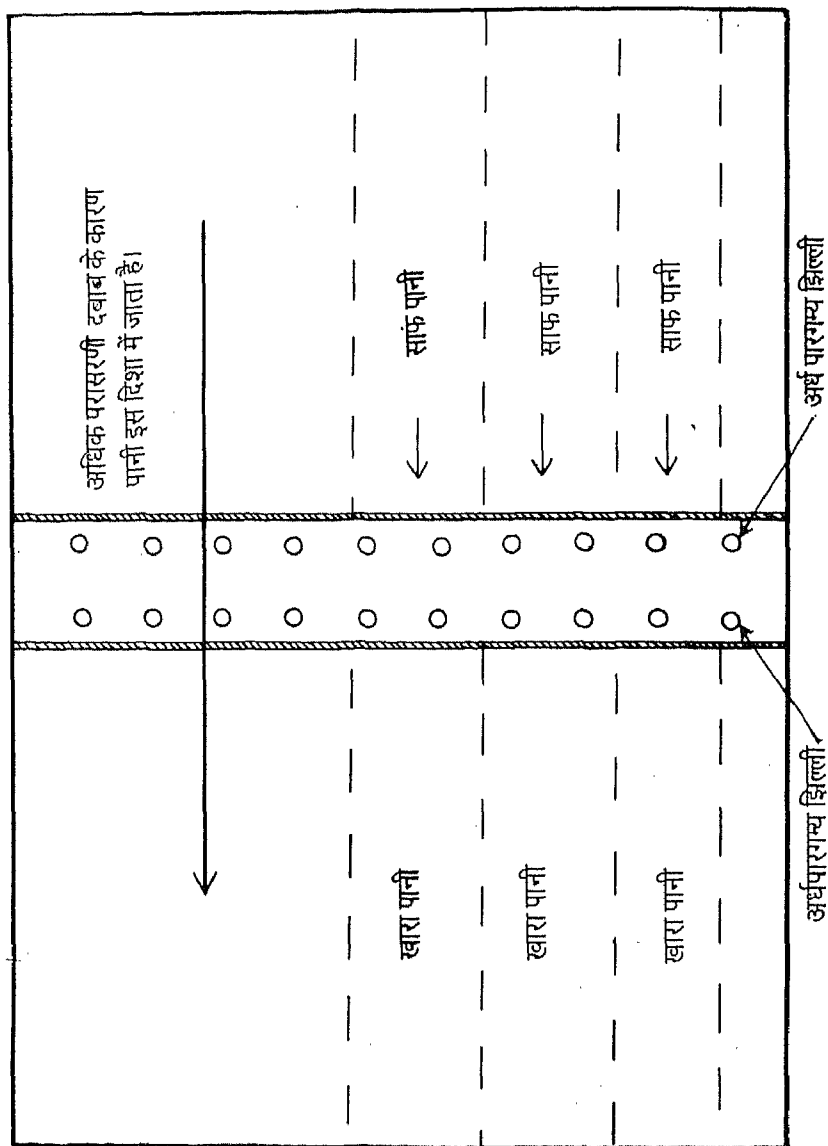
सामुद्रिक जल (Sea Water) : जहाँ लवणता 30,000 भाग से ऊपर प्रति मिलियन भाग में (अर्थात् लवण की मात्रा 3% से अधिक)।

रामू अभी तुम देख रहे हो कि पीने का पानी या पेय जल में लवण की मात्रा ज्यादा से ज्यादा 0.1% के नीचे होनी चाहिए। समुद्र पेय जल का एक अक्षय स्रोत हो सकता है अगर इससे विलवणीकरण करके जल प्राप्त किया जाये जिसमें लवण की मात्रा 0.1% से, नीचे हो। कच्छ, सौराष्ट्र, राजस्थान, हरियाणा, उड़ीसा और तमिलनाडु तथा कई अन्य क्षेत्रों में लोग अभी भी खारा जल पीते हैं जहाँ पानी में लवण की मात्रा 0.1% से भी ऊपर है। लवण मात्रा की अधिकता होने के अलावा रासायनिक द्रव्यों की मात्रा भी अधिक होने से कभी-कभी जल पीने योग्य नहीं रह पाता। ऐसे जल में फ्लुओरिन की मात्रा अधिक होती है। जिससे फ्लुओरोसिस (Fluorosis) की बीमारी हो जाती है।''

''क्या होता है जब मनुष्य को फ्लुओरोसिस हो जाती है?'' रामू पूछ बैठा।

भू-वैज्ञानिक ने उत्तर दिया, ''जब मनुष्य को फ्लुओरोसिस हो जाती है तो उसकी हड्डियाँ भी रोगग्रस्त हो जाती हैं। इससे शरीर का रूप विकृत हो जाता है।''

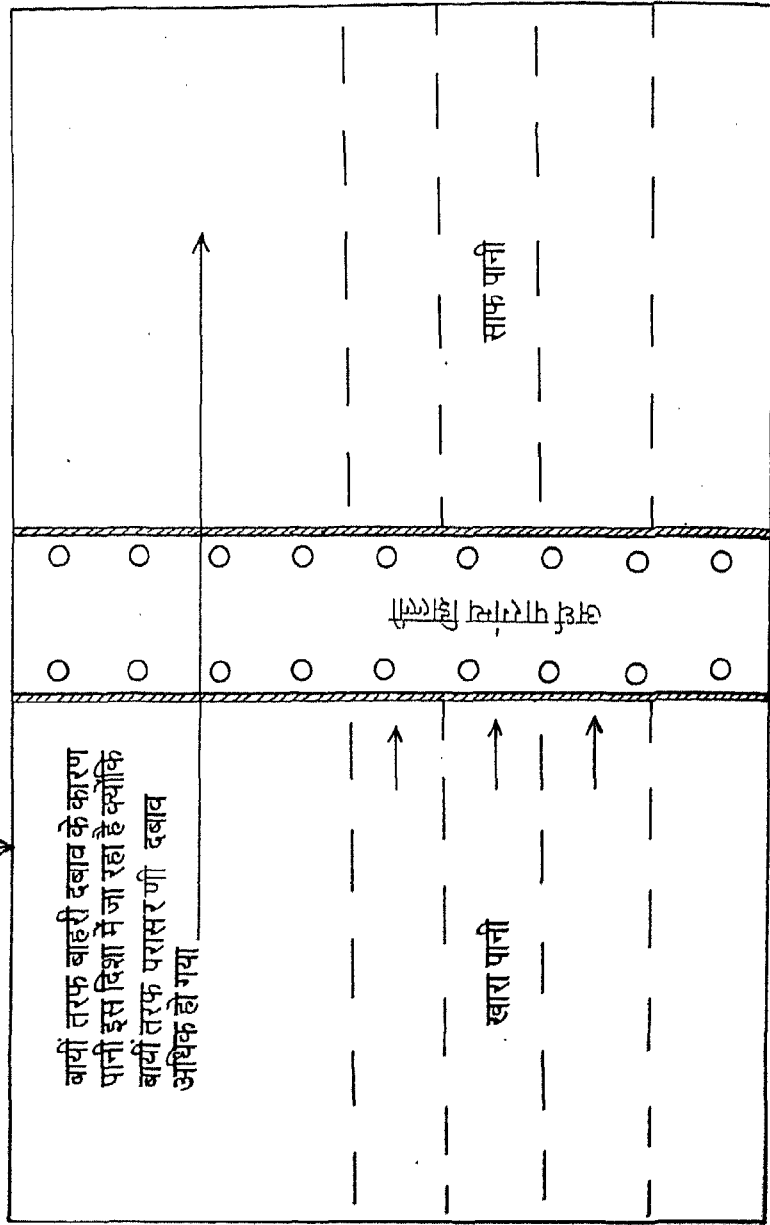
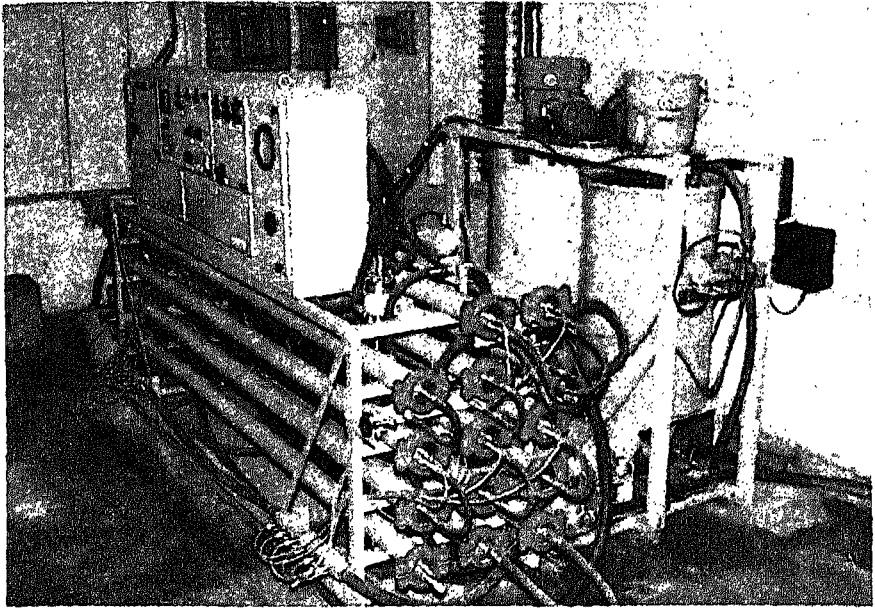
भू-वैज्ञानिक ने आगे विवरण दिया– ''भारत के प्रधान तटीय नगर विशेष रूप से बम्बई, कलकत्ता, मद्रास तथा विशाखापट्टनम में वर्तमान में पेय जल का वितरण अपर्याप्त मात्रा में है। इसके अलावा नल में जो जल पाया जाता है वह अशुद्ध होता है। इसीलिए पानी को उबाल कर पीने के लिए कहा जाता है। भारत में कई संस्थाओं में समुद्र जल या खारे जल को पेय जल में बदलने के लिए पर्याप्त अनुसंधान किये जा रहे हैं। ये अनुसंधान संस्थाएँ हैं :–

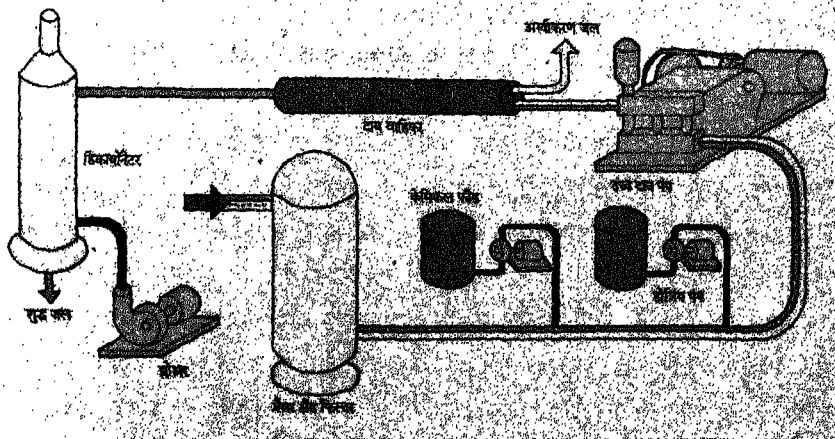
i. सेन्ट्रल साल्ट एण्ड मैरिन केमिकल्स रिसर्च इंस्टीट्यूट, भावनगर, गुजरात।
ii. भाभा एटाँमिक रिसर्च सेंन्टर, बम्बई।
iii. डीफेन्स रिसर्च लेबोरेटरी, जोधपुर।

चित्र 39 : परासरणी दाब

सेन्ट्रल साल्ट एण्ड मैरिन केमिकल्स रिसर्च इन्स्टीट्यूट खारे जल का विलवणीकरण **विपरीत परासरण** (Reverse Osmosis) की विधि द्वारा कर रहा है। भाभा एटोमिक रिसर्च सेन्टर भी इस विधि का प्रयोग कर रहा है। तुम्हें मैं इस विधि का संक्षिप्त विवरण देना चाहूँगा।

विपरीत परासरणी विधि (Reverse Osmosis Technique) : चित्र-39 में प्रदर्शित विधि में दाहिनी ओर साफ पानी है जबकि बाई ओर खारा पानी या गाढ़ा (तेज) नमक का घोल। इन दोनों के बीच एक अर्धपारगम्य झिल्ली (Semipermeable Membrane) की एक दीवार है। ऐसा देखा गया है कि अधिक से अधिक जल झिल्ली द्वारा साफ पानी से तब तक खारे पानी की ओर जाता रहता है जब तक खारे पानी में नमक का सान्द्रण साफ पानी में उपस्थित लवण सान्द्रण के बराबर न हो जाए। यह परासरणी दाब (Osmotic Pressure) के कारण होता है। दाहिनी ओर साफ पानी में परासरणी दाब अधिक होता है तथा पानी अधिक परासरणी दाब से बांयी ओर कम परासरणी दाब की तरफ जाता है। यह विधि परासरण (Osmosis) के नाम से जानी जाती है।

विपरीत परासरणी दाब उस स्थिति में पाया जाता है जब उपरोक्त नियम विपरीत होता है। ऐसा देखा गया है कि बाहरी दाब के कारण जल विपरीत दिशा की ओर ले जाया जा सकता है जैसे अधिक गाढ़े घोल से कम गाढ़े घोल की ओर (चित्र 40)। खारे जल के ऊपर बाहरी दाब लगाने से बायें हाथ से पानी अर्धपारगम्य झिल्ली द्वारा दाहिने हाथ की ओर ले जाया जाता है। इस प्रकार पानी दाहिने हाथ की ओर जाता रहता है और बायीं ओर खारेपन की मात्रा बढ़ती जाती है। यह विधि **विपरीत परासरण** (Reverse Osmosis) कहलाती है।

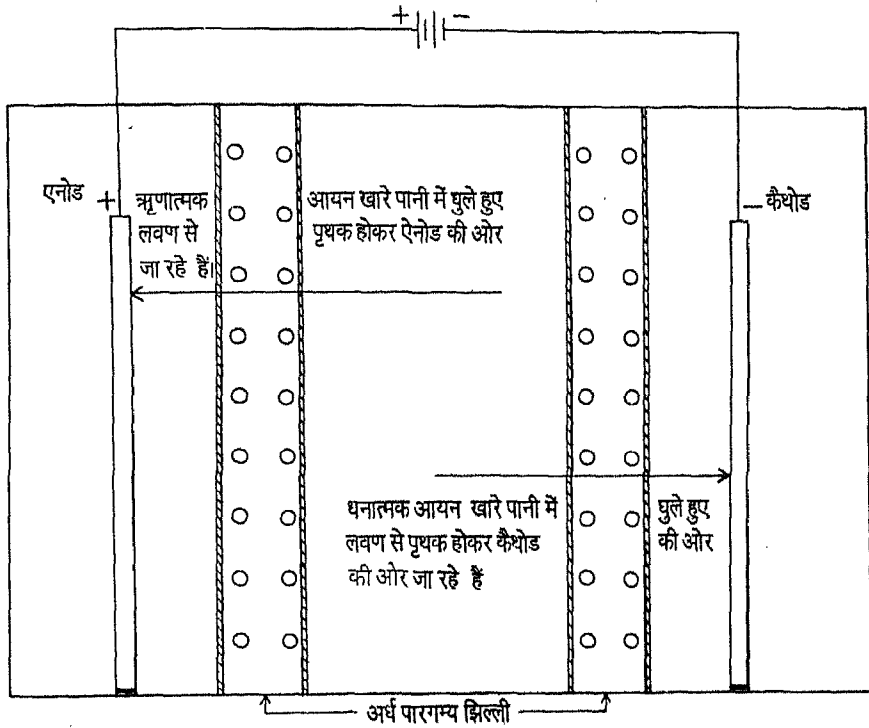
विपरीत परासरण की मुख्य विधियों पर कार्य करते हुए सेन्ट्रल साल्ट एण्ड मैरिन केमिकल्स रिसर्च इंस्टीट्यूट (भावनगर) ने खारे जल से पेय जल में परिवर्तन करने की यह तकनीक अपनायी है। (चित्र-41 क और ख)। यह तकनीक **भारत हैवी इलैक्ट्रिकल्स लिमिटेड** (भेल) को सौंप दी गई है। भारत हैवी इलैक्ट्रिकल्स लिमिटेड ने **महासागर विकास विभाग** की सहायता से दो प्रारंभिक संयंत्रों की

चित्र 40 : विपरीत परासरण

चित्र 41 क : विपरीत परासरण प्रणाली अपनाता हुआ प्रारंभिक संयंत्र

चित्र 41 ख : प्लो डायग्राम *(सेंट्रल साल्ट एंड मैरिन कैमिकल्स रिसर्च इंस्टीट्यूट, भावनगर के सौजन्य से)*

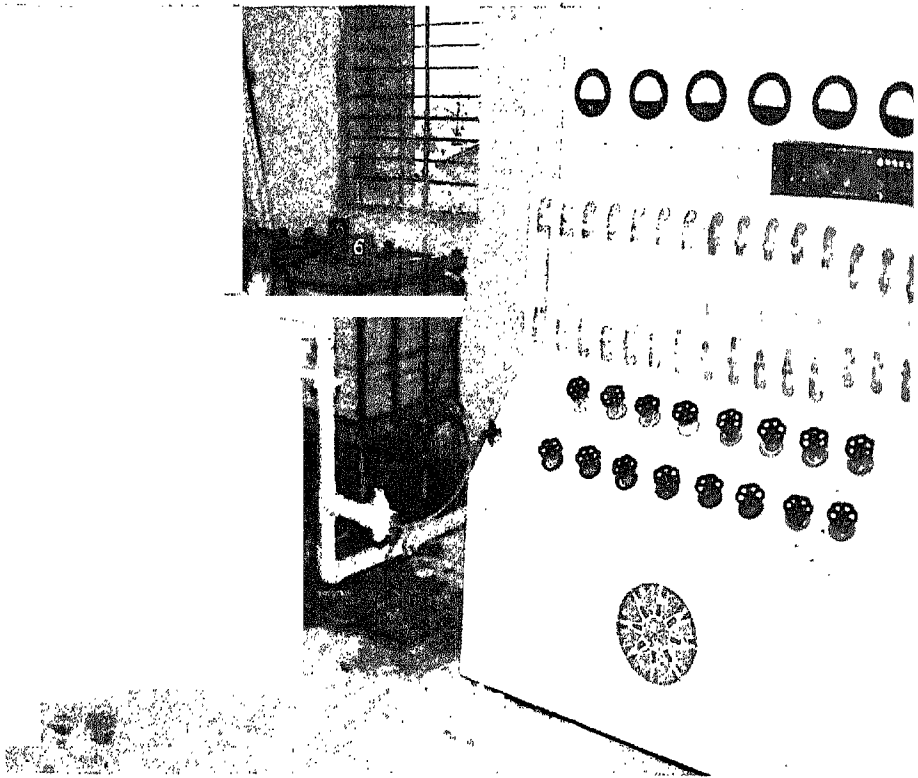
स्थापना की है। एक संयंत्र तमिलनाडु के पुथागरम नामक गांव में स्थापित किया गया है। यह संयंत्र खारे पानी से 50,000 लीटर पेय जल प्रतिदिन उत्पन्न कर सकता है। इसी प्रकार एक दूसरा संयंत्र आन्धप्रदेश के गिल्लेडुपाडु नामक गांव में स्थापित किया गया है। ये दोनों संयंत्र उन ग्रामवासियों को पेय जल दे रहे हैं जिनको यह पर्याप्त मात्रा में पहले नहीं प्राप्त होता था। इन सभी स्थानों के ग्रामवासी बहुत गरीब हैं इसलिए वे पेय जल के लिए कोई उचित व्यवस्था नहीं कर पाते थे। उन सभी ग्रामवासियों ने इन संयंत्रों के लगाए जाने का स्वागत किया। इन संयंत्रों द्वारा जल बहुत स्वच्छता से उत्पन्न किया जाता है। जल में पाए जाने वाले हानिकारक लवण, फ्लुओराइड तथा अपद्रव्य इत्यादि वस्तुएँ अब इस पेय जल में नहीं पाई जाती हैं। एक और बात, रामू जो मैं तुम्हें बताना चाहता हूँ वह यह है कि खारे जल का विलवणीकरण करके स्वच्छ जल प्राप्त करना बहुत खर्चीला काम नहीं है। इस विधि से पेय जल बनाने में कुछ ही पैसे प्रति लीटर का खर्च आता है।

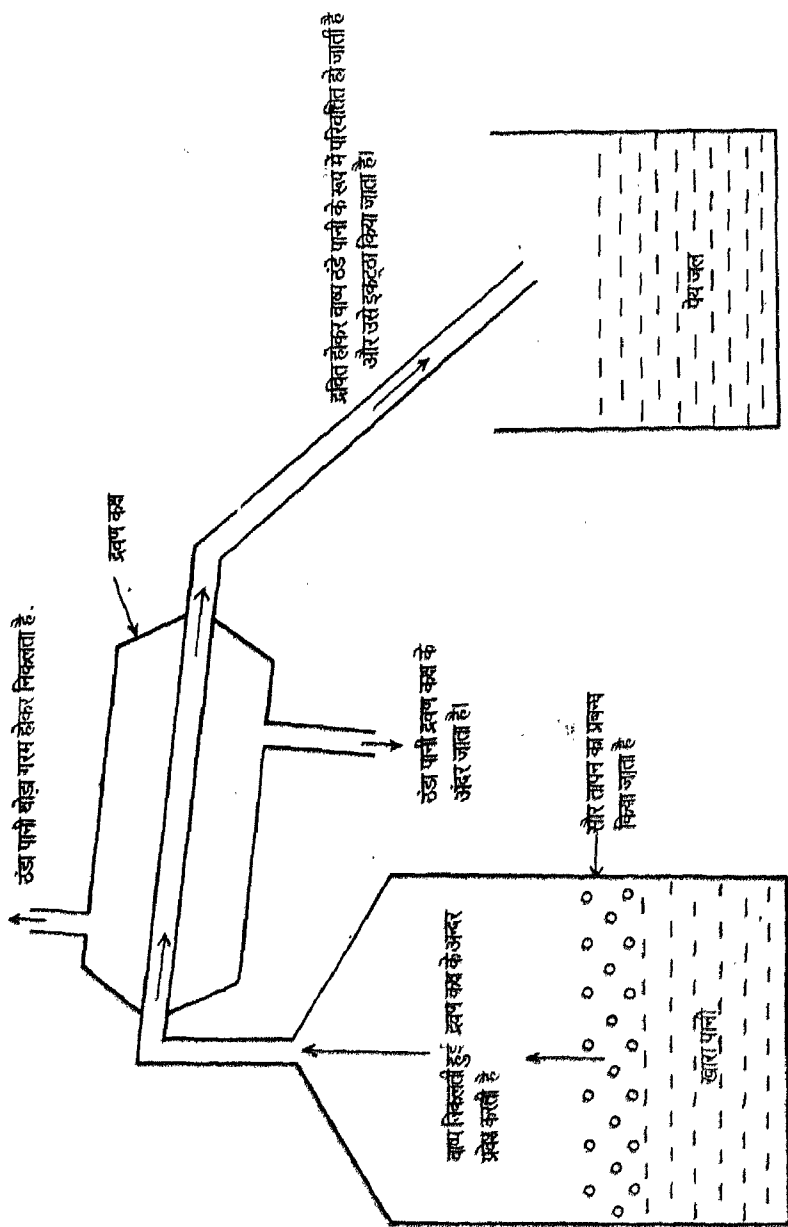
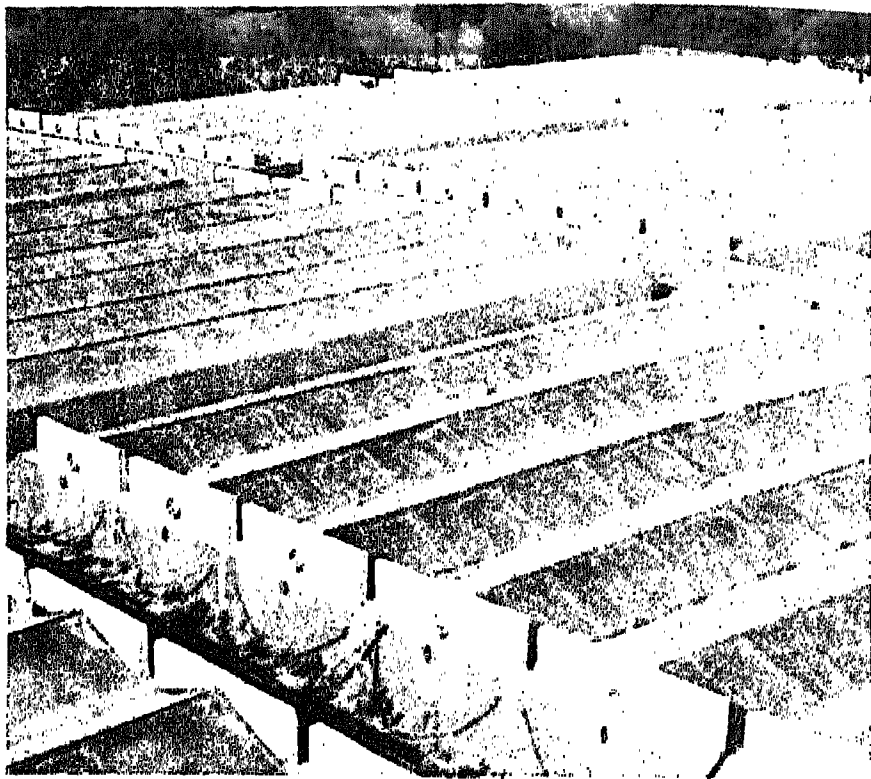
विद्युत अपोहन प्रणाली (Electro dialysis) : विपरीत परासरण विधि के साथ-साथ और भी विधियाँ खारे जल को परिवर्तित करके पेय जल बनाने के काम में आती हैं। इस विषय में अनुसंधान करके और दो प्रधान विधियाँ यथा–विद्युत अपोहन, तथा सौर तापन पर काम किया जा रहा है।

पहली विधि के अनुसार खारे जल में घुलित लवण विद्युत आकर्षण द्वारा निकाल दिया जाता है। इस विधि को साधारण रूप से समझाया जा सकता है (चित्र 42)।

जैसा कि तुम जानते हो कि जब लवण जल में घुलता है तो वह धनात्मक तथा ऋणात्मक कणों में विभाजित हो जाता है। ये आयन कहलाते हैं। धनावेशित आयन धनायन कहलाते हैं। ये ऋणात्मक इलेक्ट्रॉड की ओर आकर्षित होते हैं, जिसे कैथोड कहा जाता है। ऋणावेशित आयन ऋणायन कहलाता है। ये धनात्मक इलेक्ट्रॉड की ओर आकर्षित होते हैं, जिसे ऐनोड कहते हैं। विद्युत आवेशित कण के पृथकीकरण की विधि **विद्युत अपघटन** (Electrolysis) कहलाती हैं। चित्र में तुम देखोगे कि खारे जल को एक झिल्ली के अन्दर रखा गया है और उस झिल्ली के बाहर ऐनोड तथा कैथोड रखे हुए है। यदि विद्युत घोल से होकर प्रवाहित की जाती है तो ऐनोड तथा

चित्र_42 : विद्युत अपोहन प्रणाली

कैथोड आयनित कण को अपनी ओर आकर्षित करता है। धीरे-धीरे जल घुलित कण से एक दम रहित हो जाता है तथा झिल्ली के अंदर खारा जल अधिक से अधिक निथर जाता है तथा अन्त में पेय जल (लवण रहित) में परिवर्तित हो जाता है। चित्र-43 में एक यंत्र प्रस्तुत किया गया है जो विद्युत अपोहन विधि का व्यवहार करता है।

सौर विलवणीकरण (Solar Desalination) : दूसरी विधि सौर विलवणीकरण है। यह कुछ विशेष नहीं। तुम जानते हो कि सौर तापन के कारण खारे या समुद्री जल से पानी वाष्प के रूप में निकलता है। यह तापशक्ति सूर्य से प्राप्त होती है। किसी पात्र में निकलते हुए वाष्प को ठण्डा किया जाता है। लवण पीछे सौर आसोत्र (Solar Still) में रुक जाता है (चित्र-44 और 45)।

चित्र 43 : विद्युत अपोहन प्रणाली का व्यवहार करता हुआ एक संयंत्र।
(सैंट्रल साल्ट एवं मैरिन कैमिकल्स रिसर्च इंस्टीट्यूट भावनगर के सौजन्य से।)

इससे पहले कि मैं इसका समापन करूँ मैं एक और विधि के विषय में बताना चाहता हूँ। सऊदी अरब, रेगिस्तान में पेय जल निकालने के लिए एक रोचक विधि के बारे में कोशिश कर रहा है। अंटार्कटिक महासागर में बहते हुए विशाल हिमशैल (Iceberg) को दो तीन हजार मील से खींचकर लाने का प्रस्ताव दिया गया है।

चित्र 44 : सौर तापन से विलवणीकरण।

चित्र 45 : सौर तापन द्वारा विलवणीकरण प्रणाली का व्यवहार करता हुआ एक संयंत्र *(सेन्ट्रल साल्ट एंड मेरिन केमिकल्स रिसर्च इन्स्टीट्यूट, भावनगर के सौजन्य से)*

हिमशैल ताजे जल का एक उत्तम स्रोत है। यह सत्य है कि इतनी दूरी से आते-आते हिमशैल धीरे-धीरे गल जायेगा। इसीलिए इसका मूल्य सामान्य से अधिक होगा परन्तु जितना भी जल अभी रेगिस्तान में पाया जाता है उसके अनुसार इसका मूल्य कम ही रहेगा।

अध्याय 10

समुद्र से ऊर्जा

(ENERGY FROM THE SEA)

भू-वैज्ञानिक ने कहा, "रामू तुमने अवश्य ही सुना होगा कि आजकल लोग ऊर्जा की समस्या के बारे में चर्चा करते रहते हैं। दिन प्रतिदिन बिजली अथवा ईंधन से प्राप्त ऊर्जा महंगी होती जा रही है। किन्तु अधिक औद्योगिक विकास के साथ-साथ अधिक बिजली की आवश्यकता पड़ती है। यह बिजली हमें कहाँ से प्राप्त हो सकती है? यह बिजली हमें समुद्र ही दे सकता है।''

रामू बहुत चकित था। "आप समुद्र से ऊर्जा कैसे प्राप्त कर सकते हैं?'' रामू ने पूछा। "यदि आप यह प्राप्त कर सकते हैं, तो मैं निश्चित ही कह सकता हूँ कि आपको और कहीं से ऊर्जा प्राप्त करने की आवश्यकता नहीं है। इस प्रकार आपको हजारों वर्षों के लिए एक साथ ऊर्जा प्राप्त हो जायेगी।''

"हाँ हाँ। तुम ठीक कहते हो,'' भू-वैज्ञानिक ने कहा। "समुद्र तो सौर ऊर्जा का एक ठोस गोदाम है। इस ऊर्जा को प्रयोग में लाते हुए ऊपरी सतह का वातावरण तथा विद्युत और लहर संबंधी सामान्य विधि के संबंध में अन्योन्य क्रिया कर सकता है। ज्वार-भाटा इन्हीं–सूर्य, चन्द्रमा तथा समुद्र के अन्योन्य क्रिया के कारण होता है। अभी मैं तुम्हें एक महासागरीय (Marine) इंजीनियर से परिचित करा देता हूँ, वे इस विषय में तुम्हें आगे बतायेंगे।''

इंजीनियर साहब रामू की दिलचस्पी देखकर बहुत खुश हुए और कहने लगे–

"मनुष्य अपनी विभिन्न आवश्यकताओं के लिए सामुद्रिक शक्ति को व्यवहार में प्रयोग कर रहा है। उसने सागर के घनत्व को व्यवहार में लाकर बड़े-बड़े जहाज चलाए तथा ज्वार-भाटाओं द्वारा समुद्री जल को बन्दरगाहों में प्रवेश कराके उनके द्वारा लवण तैयार किया। हाल ही में समुद्र से ऊर्जा तथा और भी कई चीजें प्राप्त करने की कोशिश की जा रही है।

(क) ज्वार शक्ति (TIDAL POWER) : विभिन्न प्रकरणों द्वारा प्राप्त की गई ज्वार शक्ति में ज्वारीय ऊर्जा ही आर्थिक तथा प्रायोगिक रूप से सराहनीय है। विश्व विख्यात प्रथम ज्वार शक्ति के स्टेशन की रांस नदी पर स्थापना का श्रेय फ्रांस के वैज्ञानिकों तथा इंजीनियरों को देना चाहिए। अब मैं तुम्हें इसका विवरण दूँगा।

रामू, तुम जानते हो कि समुद्र सतह से जल के आवर्ती चढ़ाव व उतार को ज्वार कहा जाता है। यह सूर्य तथा चन्द्रमा के गुरुत्वीय आकर्षण (Gravitational Attraction) के कारण समुद्र जल में विभिन्न प्रकार की मात्रा में उत्पन्न होता रहता है। ज्वार परिसर 0.2 से 15 मीटर ऊँचा या इससे भी अधिक विश्व के विभिन्न तटीय प्रदेशों में पाया जाता है। ज्वार शक्ति तभी उत्पादित होती है जब दो बेसिनों के स्तरों में अन्तर उत्पन्न किया जा सके तथा उसमें भी एक बेसिन समुद्र हो। शक्ति उत्पादन के लिए लघु ज्वार भाटा की औसत परिसर कम से कम 90 सेंटीमीटर का होना आवश्यक है। यह विधि बहुत सरल है। ज्वार तरंग टरबाइन को घुमाता है। यह घूमता हुआ टरबाइन बिजली का उत्पादन करता है।

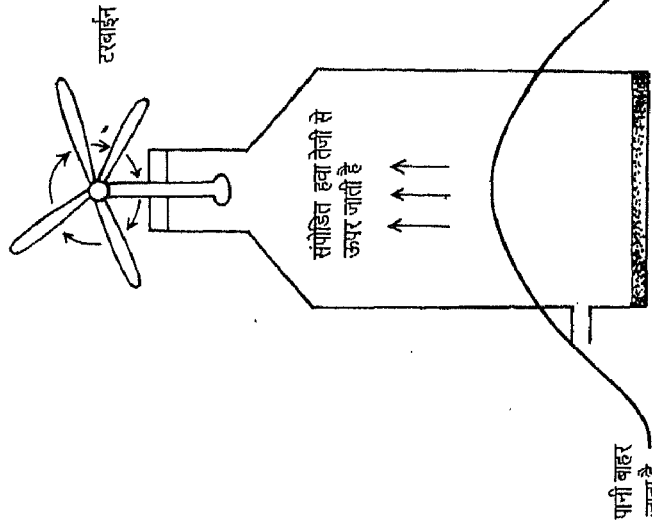
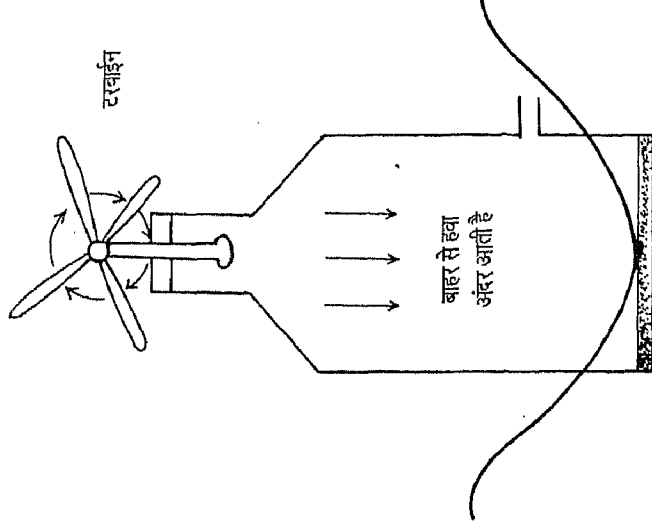
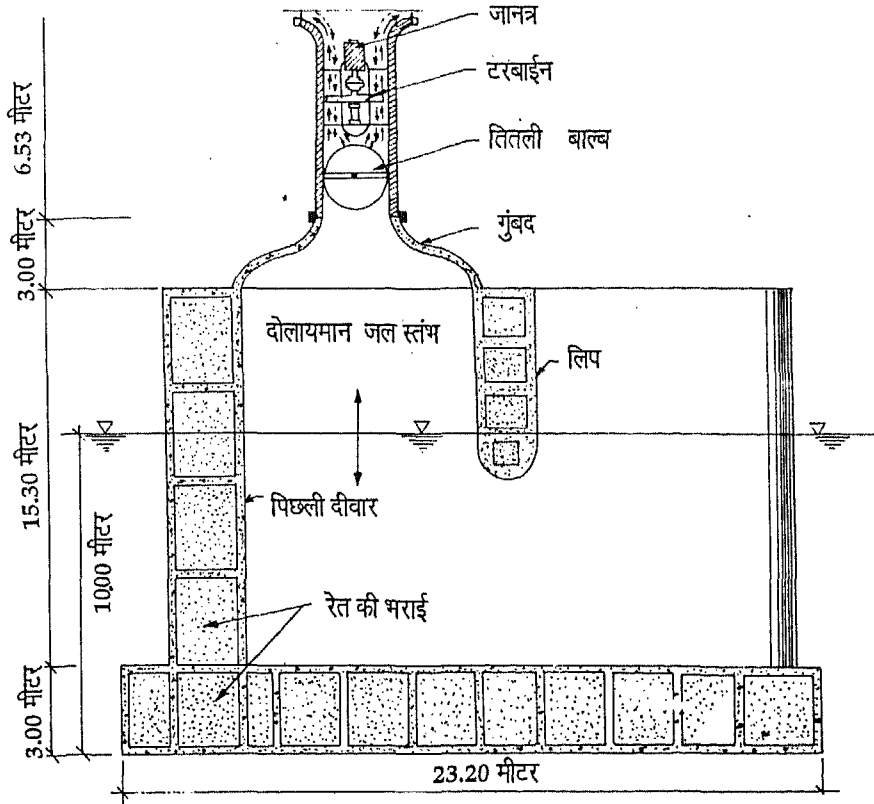
भारतवर्ष में ज्वार द्वारा विद्युत उत्पन्न करने के उचित स्थान का अध्ययन किया जा रहा है। सैंट्रल इलेक्ट्रीसिटी अथोरिटी तथा सैंट्रल वाटर एंड पावर कमीशन ने तीन संभावित स्थान निश्चित किये हैं–

i. कैम्बे की खाड़ी (गुजरात में)
ii. कच्छ की खाड़ी (गुजरात में)
iii. पश्चिमी बंगाल का सुन्दरवन इलाका

(ख) तरंग ऊर्जा (WAVE ENERGY) : इंडियन इंस्टीट्यूट ऑफ टेक्नोलॉजी (आई.आई.टी.) मद्रास सामुद्रिक ज्वार भाटा के सम्बन्ध में विशेष रूप से काम कर

रहा है तथा कार्य की तकनीकी विशेषता उपलब्ध करा रहा है। इस तकनीक के विकास में महासागर विकास विभाग अपनी आर्थिक सहायता दे रहा है तथा मार्गदर्शन भी कर रहा है।

यद्यपि अनेक संभावित तरंग ऊर्जा की रूपांतरण, तकनीकें विद्यमान हैं लेकिन, उनमें से केवल थोड़ी सी ही ऐसी हैं जिनको हम बड़े पैमाने पर इस्तेमाल कर सकते हैं। जैसे दोलायमान जल कालम (Oscillating Water Column)। इस प्रणाली की विद्युत उत्पादन क्षमता 0.5 मेगावाट तक ही सीमित है। भारत में तरंग विद्युत उत्पादन के लिए उपयुक्त प्रौद्योगिकी के विकास पर 1982 से कार्य किया जा रहा है। आई.आई.टी., मद्रास में प्रयोगशाला स्तर पर एक दोलायमान जल कालम युक्ति को पहले डिजाइन करके उसकी जाँच कर ली गई है। परियोजना के इस चरण को महासागर विकास विभाग द्वारा सहायता दी गई और इसके लिए धन की व्यवस्था भी की गई। इस प्रयोजन के लिए दो संभावित स्थलों पर विचार किया गया था जिनमें से एक स्थल मद्रास तट पर और दूसरा स्थल त्रिवेन्द्रम के पास है। प्रथम समुद्री परीक्षण के लिए त्रिवेन्द्रम के निकट के स्थल को विद्युत तथा अन्य स्थल विशेष लाभों के लिए सर्वोत्तम पाया गया है। सामुद्रिक परीक्षण सफलतापूर्वक पूरा हो जाने पर यह आशा की जाती है कि यह युक्ति मानसून के महीनों में जून से सितम्बर तक 120 किलोवाट और अधिक से अधिक 150 किलोवाट तक विद्युत पैदा कर सकेगी। चित्र-46 में दिखाया गया है कि दोलायमान जल कालम में तरंग ऊर्जा कैसे प्रस्तुत की जाती है। चित्र-47 में तरंग ऊर्जा के उत्पादन का एक शोधित रूप प्रस्तुत किया गया है।

अभी मैं तुम्हें आई.आई.टी. मद्रास की बनाई हुई तरंग ऊर्जा युक्ति के बारे में और कुछ बताना चाहता हूँ। यह युक्ति 2500 टन वजन वाला एक कंक्रीट बाक्स (दोलायमान जल कालम) है जिसे केसन कहते हैं। इसका आकार 13 मीटर × 19 मीटर × 17 मीटर होता है तथा इस पर 2 मीटर व्यास वाली एक वायु टरबाइन का विद्युत मॉड्यूल रखा गया है। आपातकाल प्रणाली को नियंत्रित करने के लिए एक उचित व्यवस्था बनायी गई जिसमें एक तितली वाल्व तथा नियंत्रण उपकरण होता है।

चित्र 46 : तरंग ऊर्जा की प्रस्तुति

चित्र 47 : तरंग विद्युत संयंत्र

तरंग रोध (Break Water) से युक्ति तक फैला 45 मीटर लम्बा एक पुल होता है जो खुले समुद्र में स्थित प्रणाली के लिए सभी प्रकार के मौसम में सम्पर्क का काम करता है। यह प्रणाली विश्व में अपनी ही तरह की एक अनूठी प्रणाली है।''

(ग) महासागरीय तापीय ऊर्जा, रूपांतरण (Ocean Thermal Energy Conversion):

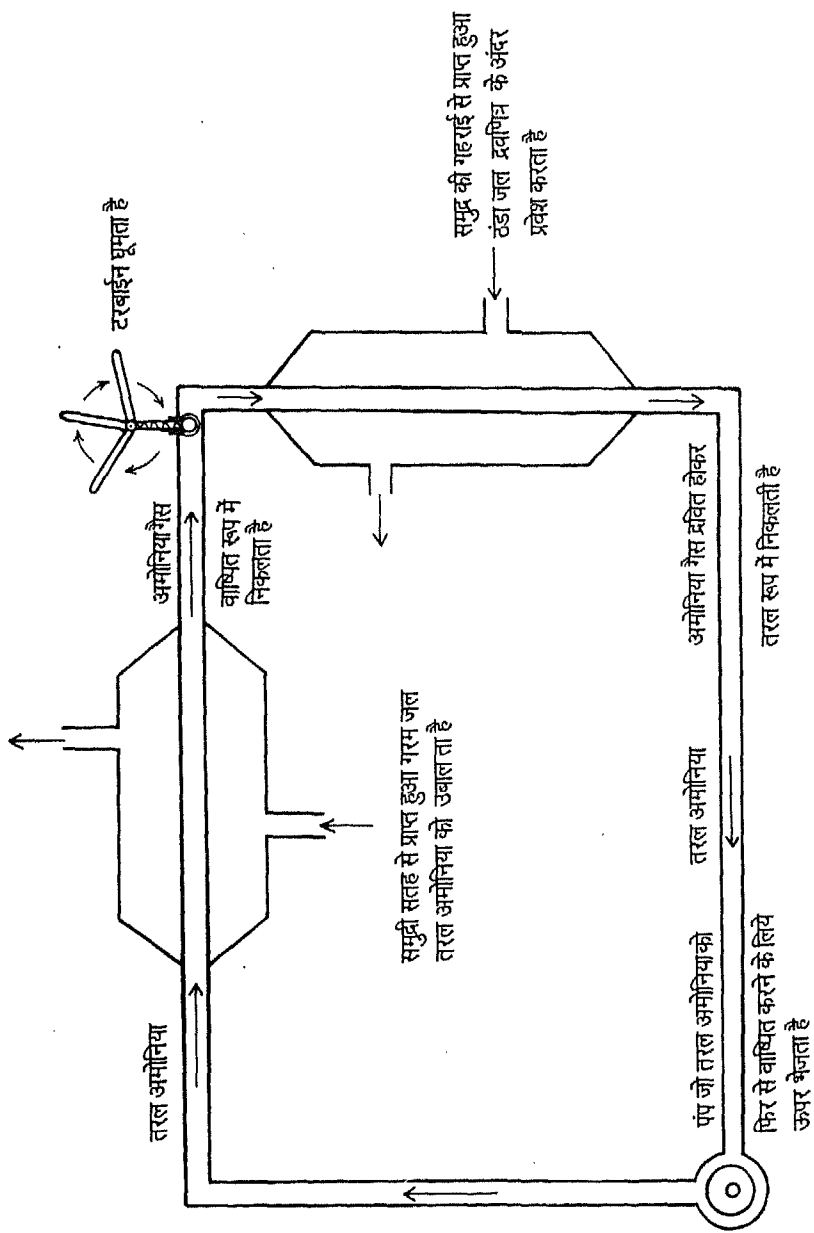
इंजीनियर साहब ने कहा, "जैसा कि तुम जानते हो कि महासागर ऊर्जा के विशाल भंडार हैं। महासागर की ऊर्जा को अनेक प्रकार से व्यक्त किया जाता है जैसे तरंगों, धाराओं, और ज्वार भाटा के रूप में। इन स्पष्ट तथा भौतिक अभिव्यक्तियों

के अलावा महासागर ऊर्जा के अन्य रूप भी हैं जो इतने स्पष्ट नहीं हैं। इनमें से एक तापीय ऊर्जा है अर्थात् वह सतह के गर्म जल और गहरे समुद्र के ठंडे जल के मध्य ताप अन्तर से उत्पन्न होने वाली ऊर्जा क्षमता है। **महासागरीय तापीय ऊर्जा, रूपान्तरण** (ओ.टी.ई.सी.) के रूप में जानी जाने वाली प्रक्रिया को उपयोग में लाना अनेक संभावनाओं में से एक है, जिसके बारे में अमरीका, जापान, नीदरलैंड तथा स्कैंडिनेवियन देशों द्वारा गम्भीरतापूर्वक विचार किया जा रहा है। जहाँ तक भारत का संबंध है, महासागरीय तापीय ऊर्जा रूपान्तरण क्षमता मुख्य रूप से लक्षद्वीप तथा अंडमान और निकोबार के आसपास की तटभूमि में अधिक मात्रा में होने का अनुमान है।

महासागर तापीय ऊर्जा रूपांतरण का सिद्धान्त बड़ा ही सरल है। यह एक ऐसी तकनीक है जिससे समुद्र सतह के गरम जल तथा समुद्र के गहरे ठंडे जल के बीच दो विभिन्न तापों से विद्युत के रूप में ऊर्जा उत्पन्न की जाती है। मुझे इसका विस्तृत विवरण देने दो।

पृथ्वी के उष्ण कटिबंधीय प्रदेशों में ऐसा देखा गया है कि सतह के जल का ताप 500–800 मीटर नीचे गहरे समुद्र सतह के जल के ताप से 25°C अधिक उच्च होगा। समुद्र तट के पास जल की इतनी गहराई में आमतौर से ताप में विशेष अन्तर नहीं पाया जाता है। केवल कुछ ही स्थानों में तट के पास ताप में ज्यादा अन्तर पाया जाता है।

महासागरीय तापीय ऊर्जा रूपांतरण प्लाँट में एक आसानी से वाष्पशील होने वाला द्रव जैसे अमोनिया होता है जो समुद्र के ऊपरी सतह के जल से वाष्पित हो जाता है और टरबाइन को विद्युत उत्पादन के लिये घुमाता है जिससे विद्युत उत्पन्न होती है। अत: विद्युत समुद्र तट पर **अंत:समुद्री केबल** (Submarine Cable) से संचारित की जाती है। इसी बीच में समुद्र की गहराई से निकाला गया शीतल जल वाष्पित हुए अमोनिया को संघनित करता है। इसी प्रक्रिया को बार-बार दोहराया जाता है। (चित्र-48)।

महासागरीय तापीय ऊर्जा रूपांतरण द्वारा बिजली उत्पादन की दो विधियाँ हैं :

चित्र 48 : ओ.टी.ई.सी. प्रणाली

महासागरीय तापीय ऊर्जा रूपांतरण खुली विधि : यहाँ सतह के गर्म सामुद्रिक जल को कम दाब में वाष्पित करके निम्न दाब की वाष्प उत्पन्न की जाती है जो अपने आप टरबाइन पर कार्य करती है और उसे घुमाती है। इस विसर्जित भाप को एक अन्य कक्ष में गहरे समुद्र से प्राप्त ठंडे जल से संघनित किया जाता है। यह संघनित पानी पीने योग्य भी होता है।

महासागरीय तापीय ऊर्जा रूपांतरण की बन्द विधि : इस विधि में समुद्र की सतह का गर्म जल अमोनिया या प्रोपेन, जैसे तरल पदार्थ (क्वथनांक 40° और 20° के बीच) वाष्पित करने के काम में आता है। यह वाष्पित पदार्थ टरबाइन को घुमाता है तथा विद्युत उत्पादन करता है। उस वाष्पित पदार्थ को फिर एक अन्य कक्ष में समुद्र की गहराई से प्राप्त ठंडे जल से संघनित करके तरल पदार्थ में पुनः रूपांतरित कर लिया जाता है।

संयुक्त राष्ट्र अमरीका में महासागरीय तापीय ऊर्जा रूपांतरण (ओ.टी.ई.सी.) विधि द्वारा 40 मेगावाट प्लान्ट बनाने का प्रयत्न किया जा रहा है।

भारत में **अपारम्परिक ऊर्जा स्रोत विभाग** (Department of Non Conventional Energy Sources) तथा **महासागर विकास विभाग** एक मेगावाट पायलट प्लान्ट की किसी उपयुक्त स्थान पर स्थापना के विषय में विचार कर रहे हैं। शुरू में लक्षद्वीप में कावरेती नामक स्थान को महासागरीय तापीय ऊर्जा रूपांतरण के लिए संभावित स्थान चुना गया था। बाद में कुछ प्रशासनिक कारणों से एक आकर्षक स्थान मिनीकाय द्वीप में तथा अंडमान निकोबार द्वीप में खोजा गया।''

रामू ने पूछा, "यदि महासागरीय तापीय ऊर्जा रूपांतरण सफलतापूर्वक स्थापित किया जाए तो उससे कितना विद्युत उत्पादन किया जा सकता है?''

"हाँ, संभावना बहुत ही है'', इंजीनियर साहब ने उत्तर दिया। "इतना देखा गया है कि 50,000 मेगावाट तक विद्युत का उत्पादन भारत में महासागरीय तापीय ऊर्जा रूपांतरण प्लान्ट द्वारा किया जा सकता है।''

निष्कर्ष

जब रामू अपने घर पहुँचा तो उसकी दादी माँ ने कहा, "रामू, पिछले कुछ दिनों से मैं देख रही हूँ कि तुम कुछ विचारों में डूबे रहते हो। इसका अर्थ यह है कि तुम किसी गंभीर विषय पर सोच रहे हो। यह विषय क्या है मुझे भी बताओगे ?''

रामू ने कहा, "दादी माँ पिछले कुछ दिनों से मैं समुद्र के संबंध में पुस्तकें पढ़ रहा हूँ। मेरी अध्यापिका ने भी मुझें समुद्र के संबंध में बहुत ज्ञान दिया। बाद में मुझे एक समुद्र वैज्ञानिक, एक भू-वैज्ञानिक और एक महासागरीय इंजीनियर से बहुत कुछ सीखने को मिला। उन लोगों से मुझे विभिन्न प्रकार के समुद्र में पाये जाने वाले पौधें, जीव-जन्तुओं, खनिजों तथा रसायनों के बारे में जानकारी हुई।''

दादी माँ ने कहा, "रामू तुम्हारी बातें सुनकर मुझे भी समुद्र के बारे में दिलचस्पी होने लगी। मुझे बहुत खुशी होगी अगर तुम समुद्र की संपदा के विषय में संक्षेप में बताओ।''

रामू जानता था कि दादी माँ बहुत शिक्षित नहीं हैं और उनसे किसी गहन विषय पर बातचीत नहीं की जा सकती। तब भी वह उनका आग्रह टाल नहीं सकता था। दादी माँ के आग्रह से प्रेरित होकर वह बोलने लगा–

"पुरातन काल से ही महासागरों का उपयोग दो मुख्य उद्देश्यों के लिए होता रहा है– एक तो मछली उद्योग के लिए और दूसरा जहाज़ी परिवहन के लिए। अभी हाल में ही समुद्र से तेल, गैस और विभिन्न प्रकार के खनिजों की खोज और सागर से ऊर्जा की प्राप्ति की संभावना ने मानव को यह विश्वास दिला दिया है कि संसार के बड़े-बड़े खजाने समुद्र में ही बन्द पड़े हुए हैं।

पृथ्वी का दो-तिहाई भाग समुद्री जल से भरा हुआ है। महासागरों में शार्क, रे मछली, सील, ह्वेल, डालफिन आदि जैसे विशाल आकार के जीवित प्राणी घूमते रहते हैं। इसी प्रकार क्रिल, झींगा मछलियाँ, लॉबस्टार, केंकड़ा, कांकल, मसल, सारडीन, ट्यूना, बांगड़ा, बंबिल, पांफेटस् भी मिलते हैं। यह तो तुम जानती ही हो कि मैं झींगा, लाबस्टार, केंकड़ा कितना पसंद करता हूँ।

वैज्ञानिकों ने समुद्र से खनिजों की खोज, उनकी गुणवत्ता, उनके भण्डार और विस्तार का पता लगाया है। समुद्री तट पर विस्तृत सर्वेक्षण के बाद मूल्यवान खनिज पदार्थों जैसे इल्मेनाइट, मैग्नेसाइट, रूटाइल की खोज हुई है। मध्य हिंद महासागर के पाँच किलोमीटर गहरे पानी से बहुधात्विक पिण्डों की खोज हुई है, जिसमें तांबा, निकेल, कोबाल्ट, मैंगनीज, जिंक आदि धातुएँ हैं। उनकी प्राप्ति की संभावना आज और भी बलवती हो गई है।

औषधि एवं भेषज आवश्यकताओं के लिए शैवाल जैसी महत्वपूर्ण सम्पदा का उपयोग किया जाता है।

दादी माँ यह तो आपने सुना ही होगा कि आजकल बम्बई के समुद्रतट से कुछ दूरी पर, अपतटीय क्षेत्र से पैट्रोलियम तथा पैट्रोलियम गैस का निकर्षण किया जाता है।

कहानी यहाँ ही खतम नहीं होती। पीने के स्वच्छ पानी की सम्पूर्ण विश्व में और विशेषकर भारत जैसे बड़े और विकासशील देश में तेजी से कमी होती जा रही है। महासागर इस संबंध में स्वच्छ पानी की आवश्यकता की पूर्ति करने में महत्वपूर्ण भूमिका निभा सकते हैं। आज खारे पानी से पेय जल की प्राप्ति के लिए कई प्रकार की प्रौद्योगिकी अपनायी जा रही हैं।

इसके अलावा महासागर ऊर्जा के भी अनन्त स्रोत माने जाते हैं। भारत के परिपेक्ष में तथा साधन क्षमता, औद्योगिकी विकास एवं अन्य फायदों के दृष्टिकोण से जो सबसे अधिक आशाजनक स्रोत हैं, वे हैं ज्वारीय ऊर्जा तथा लहर ऊर्जा। इन दोनों के उपयोग के लिए आज हमारे पास प्रौद्योगिकी उपलब्ध है।''

दादी माँ अभी तक रामू की बातें ध्यानपूर्वक सुन रही थी। उन्होंने बीच में ही टोकते हुए कहा "राम भारतीय पौराणिक कथाओं में ऐसा प्रसंग आया है जिसमें

देवताओं और दानवों ने मिलकर समुद्र का मंथन किया था। इस मंथन के परिणामस्वरूप अमृत, लक्ष्मी, ऐरावत हाथी, उच्चैश्रवा घोड़ा, कल्पद्रुम, रत्न, आदि अनेक मानवोपयोगी उपहार प्राप्त हुए थे। यह पौराणिक कथा भले ही अतिरंजित प्रतीत होती हो परन्तु तुम्हारी बातों से यह लगता है कि मंथन की सत्यता कुछ हद तक प्रमाणित हो रही है।''

"हाँ-हाँ दादी माँ तुमने ठीक ही कहा,'' रामू बोला। "पुराण की इस कथा से यह स्पष्ट संकेत मिलता है कि हमारे पूर्वज महासागर की उपादेयता को भली-भाँति समझते थे। और वे इसके गर्भ में छिपी हुई किसी सम्पदा की खोज की दिशा में अग्रगण्य रहे। धरती पर पाये जाने वाली खाद्य सामग्री तथा प्राकृतिक संसाधन तेजी से बढ़ती हुई आबादी के लिए कम पड़ते जा रहे हैं, इस भावी संकट से उबरने का एक मात्र विकल्प वस्तुतः समुद्र ही दिखाई पड़ता है। कोई आश्चर्य नहीं कि आज महासागरों को हम आखिरी सीमाओं (Last Frontier) के रूप में मानने लगें।''

रामू आगे बोलता गया "इस संदर्भ में यह कहना उचित होगा कि समुद्र का जल अनेक कारणों से प्रदूषित होता जा रहा है। बढ़ते हुए औद्योगीकरण ने इस समस्या को और भी गंभीर बना दिया है। प्रत्यक्ष या परोक्ष रूप से यह समुद्री जल को दूषित कर जीव जन्तुओं के लिए संकट उत्पन्न कर रहा है। रासायनिक उद्योग, उर्वरक बनाने वाले उद्योग, कागज के कारखाने, वस्त्र उद्योग, तेलशोधक कारखाने, आदि समुद्री प्रदूषण के कारण हैं। इसीलिए जहाँ पर समुद्र से सम्पदा की खोज और उनको उपयोग में लाने के लिए प्रयत्न जारी हैं, वहीं साथ-साथ यह भी प्रयत्न जारी है कि समुद्री प्रदूषण को भरसक रोका जाय। आशा है कि हम इस प्रयास में अवश्य सफल होंगे। अगर ऐसा हुआ तो आने वाली कई शताब्दियों तक मनुष्य जाति की मांगों की पूर्ति इन महासागरों से ही होती रहेगी।''

अनुबन्ध

नीचे कुछ पुस्तकों तथा प्रकाशित सामग्री की एक सूची दी गई है। प्रस्तुत पुस्तक इनके आधार पर लिखी गई है। महासागर के विविध संसाधनों के बारे में और अधिक जानकारी प्राप्त करने के लिए इनका अध्ययन किया जा सकता है।

1. ओशनोग्राफी (Oceanography) — चार्लस एल ड्रेक, जॉन ईमब्री, जॉन ए नाउस एवं कार्ल के तुर्कियान
2. दी सीज एंड दी ओशनस (The Seas and the Oceans) — सी.एफ. हिकलिंग एवं पीटर लेंकेस्टार ब्राउन
3. दी वंडरफुल वर्ल्ड ऑफ दी सी (The Wonderful World of the sea) — जैम्स फीशार
4. लाइफ इन दी ओशनस् (Life in the Oceans) — जोसेफ लुकास एवं पैमेला क्रीच
5. पेंग्विन के देश में — सैयद जहूर कासिम एवं प्रभात नाथ मुकर्जी
6. लाइफ इन दी ओशनस् (Life in the Oceans) — हैथार ऐंजल
7. बनडर्स ऑफ दी सी (Wonders of the Sea) — राबर्ट बार्टन, कैरल डीवार्न एवं टोनि लांग
8. पैट्रोलियम एंड हार्ड मिनरल्स फ्रॉम दी सी (Petroleum and Hard Minerals From the Sea) — फिलमोर सी. एफ. आर्ने
9. दी सी फेयरर्स गाइड टु मैरिन लाइफ (The Seafarers Guide to Marine Life) — पाल वी हार्समैन
10. सी.सी.एम.एल.आर. की वैज्ञानिक समिति 1982-84 के सामने प्रस्तुत की गई रिपोर्ट (भाग 1 से चुने हुए कुछ निबंध)
11. महासागर विकास विभाग की सात साल की वार्षिक रिपोर्ट (अप्रैल 1983 से मार्च 1993)

and rarely or never used others For example, one subject often threw his head back, wrinkled his forehead, and opened his mouth, but never showed vertical wrinkles between the eyebrows Another subject usually pursed his lips, but never threw his head back One subject almost always closed his eyes, another opened them widely The reason for such variations in expression is not clear Questioning the subjects themselves shed no light upon the problem Many subjects did not know what facial reactions they characteristically showed, whereas others, though aware of their reactions, were unable to explain them However, it was found that in many individuals these differences in facial expression were due more to the failure of certain muscles to function at all than to the occurrence of very marked and intense reactions of the participating muscle groups Probably, many personal "mannerisms" are similarly due more to the nonfunction of specific groups of muscles than to the overfunction of others

The Relationship between Situation and Facial Expression It is a common popular belief that in a given emotional situation most individuals will show a facial expression which is sufficiently specific and distinctive to reveal the nature of the emotion aroused This view was sponsored by Darwin,[1] who wrote, "We have seen that frowning is the natural expression of some difficulty encountered or of something disagreeable experienced, either in thought or in action, and he whose mind is often and readily affected in this way will be apt to be ill-tempered or slightly angry or peevish, and will commonly show it by frowning "

No evidence in favor of this view was found in the foregoing experiment No given expression was present in enough photographs taken under the same or very similar conditions to be considered as typical of any situation Smiling occurred more frequently than any other response, but even this reaction was not associated with any particular situation

The Relationship between Verbal Reports of Emotion and Facial Expressions. Pictures which had been taken when the subjects reported definite emotions, such as "disgust," "exasperation," "anger," "revolting," "surprise," and "sex excitement," were carefully analyzed Contrary to commonly held views, there were no facial expressions

[1] Darwin, C *The Expression of the Emotions in Man and Animals* 2d ed, p 238, London, 1890

which showed any clear correlation with any verbally reported emotion. To be sure, in every picture taken during "exasperation" the subject's lips were open But the prevalence of this reaction was due merely to the fact that all the "exasperation" pictures were taken in situations 10 and 16, in which the subjects were multiplying by the talking aloud method

Posing and Facial Expression. Three of the subjects who had served in the experiment were asked to "register" or "act out" the facial expressions corresponding to certain emotions which they had verbally reported as having experienced during the situation series. With these instructions they gave expressions which could for the most part be readily recognized as the traditional expressions of "religious feeling," "disgust," "fear," and so on That is, their expressions then took the form of the definite facial patterns which we have traditionally regarded as expressive of certain emotions or feelings But these expressions were not the ones they showed in the experimental situations when these emotions were actually present In reality, these posed expressions were probably only socially learned and socially approved expressions in the nature of language gestures and did not reproduce the patterns of facial expressions which actually occur in real emotional situations

Sex Differences For the most part, the facial changes of the male subjects were found to be more expressive and dynamic than were those of the females Also, in situations 15 and 16 certain differences in the general behavior of the two sexes were noted During the decapitation of the rat, and also during the electrical punishment, seven of the women cried and begged the experimenter to stop the experiment In situation 16 the male subjects became profane, a number of them tore off the electrode which was attached to the arm and threw it in the direction of the experimenter; several *demanded* that the electrical stimulation be stopped However, no evidence for sex differences in the variety of facial expressions was found in the photographs from either situation

DISCUSSION

The major result of Landis's experiment is that no common or describable correspondence was discovered, either between any specific facial expression and any of the situations employed or between any

facial expression and any one kind of emotion (such as fear, anger, disgust) which the subjects reported. Whether the same results would be obtained with different subjects and with a wider range of stimuli is a question which cannot now be decisively answered. However, neither common sense nor traditional beliefs are adequate to solve such a problem. To most psychologists, Landis's results strongly suggest that the emotions which we introspectively differentiate are not distinguished by characteristic and different facial expressions.

II. AN EXPERIMENT ON THE JUDGMENT OF FACIAL EXPRESSION IN EMOTION[1]

As we have already pointed out, various experiments have been performed in which photographs of posed or simulated facial expressions have been shown to groups of observers who were instructed to decide what emotion was portrayed in each picture. Under these conditions, it is found that ordinary observers can infer what emotion is depicted more often than chance would account for. But this finding does not justify the conclusion that observers would be equally successful in judging photographs of "real" facial expressions produced under the stress of actual emotion. Obviously, an experiment in which *real* and not posed expressions are judged is necessary to answer the question which this statement implies. Landis, by proceeding to use certain of the photographs obtained in the experiment just described, was able to carry out a study of this further and different type.

PURPOSE

The specific aims of this experiment were as follows.

1. Given a collection of photographs taken during "real" emotional situations, to determine what interpretations judges will place on the "emotions" portrayed.
2. To determine whether a judge can describe correctly the situation which aroused the expression shown in a particular portrait.
3. To determine whether one can interpret more accurately the "emotion" when a portrait depicts a real response to an actual situation, or when it depicts an acted response to an imagined situation.

[1] Adapted from Landis, C. The Interpretation of Facial Expression in Emotion. *Journal of General Psychology*, 1929, vol. 2, pp. 59–72.

METHOD

Seventy-seven photographs were selected from the 844 taken in the previous experiment. These particular pictures were chosen because the investigator thought they were "very expressive." Of the 77 pictures, 56 were taken in actual emotional situations, while the other 21 were of subjects who were giving acted responses to an imaginary reinstatement of the situations they had previously experienced. Pictures of 11 men and 11 women were used. Each picture was trimmed so that only the head and shoulders were shown.

The pictures were projected on a screen by a projection lantern. The judges were 42 students of psychology at Connecticut Wesleyan University. Each judge was given a set of mimeographed blanks. At the head of each set of blanks were the following instructions: "You will be shown a series of photographs which seem to be expressive of various emotions or feelings. Consider each photograph carefully and then try to state what emotion or feeling you think the subject is experiencing. Enter this in the first column opposite the number of the picture. Then try to imagine or guess what sort of stimulation would give the particular expression photographed. Enter this in the second column. In the third column enter the percentage of certainty you feel concerning your two previous judgments."

RESULTS

The results of the experiment may be briefly summarized as follows:

1. The titles given to the photographs taken in emotional situations were mainly such terms as "joy," "sorrow," "maternal," and "surprise." In some cases, two somewhat contradictory terms were applied to the same picture by the same individual.

2. In most cases, when the observers were asked to characterize the situations which might give rise to the expressions shown in the photographs, they made use of only four general terms: "pleasant," "unpleasant," "religious," and "maternal." For eight of the photographs the mutually contradictory terms "pleasant" and "unpleasant" occurred in more than 20 per cent of the judgments. One picture was classified as appropriate for a pleasant situation in 46 per cent, and for an unpleasant one in 49 per cent of the judgments.

3. Only 31 per cent of the judgments of the emotions depicted in

the "real" pictures agreed with the introspective reports of the subjects photographed Similarly, for the posed pictures, only 28 per cent of the judgments were found to agree with the emotions which the pictures were intended to portray As to the ability of the judges to name situations which might have given rise to the emotions shown, 43 per cent of the judgments of the "real" pictures and 38 per cent of the judgments of the posed pictures were classified by the experimenter as "appropriate" Hence, there was no significant difference in the accuracy with which the judges interpreted photographs which depicted "real" expressions in actual emotional situations and photographs which depicted posed expressions in imagined situations

Discussion

How can the results of these experiments be reconciled with those of investigators who have found that pictures representing various emotional reactions could be named correctly by observers more frequently than would have been possible had they been merely guessing? Landis believes that the explanation of the differences between his results and those of others lies in the fact that the posed pictures previously used were not true portraits of facial expression during emotion, but rather were pictures of the socialized and, to a large extent, conventionalized reactions which are used as supplementary language mechanisms There is little or no evidence that such expressions occur in "real emotion" except by chance To be sure, Landis's posed photographs were judged no more accurately than were his photographs taken in actual emotional situations, but this somewhat surprising result may be due merely to the fact that his subjects were "poor actors," *i e*, they were unpracticed in acting and unable to produce correctly the conventional facial expressions

Are we, then, to conclude that no facial expressions of emotional origin can be interpreted correctly, and that the general belief to the contrary is wholly mistaken? The answer to this question seems to be an affirmative one What happens in most cases of so-called "reading emotion from the face" is that we observe not only the facial expression of an individual but also many other perceptible aspects of his behavior (*e g*, verbal, gestural, and postural signs), and, especially important, we observe, as well, the situation which is stimulating him We may think that we are judging the nature

and degree of his emotional reactions on the basis of his facial expression alone But in actual fact, it is very probable that the other factors mentioned above generally contribute far more to our interpretation As Landis's experiment shows, when we are forced to judge emotions from the face only, we have little or no basis for success in differentiating one emotion from another

CHAPTER VIII

THE DUPLICITY THEORY OF VISION

Introduction

The retina of the human eye contains two kinds of receptor cells, the rods and the cones. These two types of cells differ with respect to their structure, their function, and their distribution within the retina. Within the *fovea centralis*[1] there are many thousands of cones, but no rods. As one passes from the center toward the periphery of the retina, the proportion of rods to cones steadily increases until, at the extreme periphery, rods are thickly distributed and there are few, if any, cones.[2]

According to the "duplicity theory" of von Kries, the cones and rods of the retina have two important differences in function. First, the cones are the receptor cells which function at daytime levels of light intensity, whereas the rods are the receptors for "twilight vision," *i.e.*, for vision at the low intensities of illumination which characterize twilight and night conditions. Second, the cones are the cells which are so constituted that they enable us to perceive colors and to discriminate color differences, whereas the rods make possible only colorless, or achromatic, vision. The evidence supporting this duplicity theory may be summarized as follows.

1. Foveal Night Blindness. It has been shown that under deep twilight conditions of illumination the fovea is in effect a *scotoma*, *i.e.*, a blind area. Many years ago astronomers observed that they could not see very dim stars when they were looking directly at them but that these same stars became visible when they turned their eyes away to view some neighboring star. Since they were now fixating the neighboring star, the light from the dim star would fall outside

[1] The *fovea centralis* is the small, central "area of clearest vision" upon which is impressed the retinal image of small objects or figures which are directly "fixated" by the observer.

[2] The total number of rods exceeds that of the cones by many millions. Estimates of the number of rods vary from 60,000,000 to 130,000,000, whereas the estimated number of cones is only about 7,000,000.

the fovea, in a retinal region where rods are known to be abundant After the rods have become "dark adapted" by being shielded from intense light for a time, they are much more sensitive to low intensities of light than are the cones Although under daylight conditions it is the foveal cones which give us our clearest visual impressions, their thresholds of excitation are much higher than are those of the rods

2. Differences in the Processes of Adaptation between the Cones and the Rods. The human retina is capable of two kinds of adaptation process, "light adaptation" and "dark adaptation" *Light adaptation* refers to the *decrease in sensitivity* of the retinal cells under continued stimulation by light, especially by light of relatively high intensity This process goes on very slowly in the cones, but in the rods it is both rapid and extensive The effect of light adaptation is illustrated by the familiar experience of being temporarily "blinded" when one goes from a brightly illuminated place into a relatively dark room The explanation of this experience is that the intensity of stimulation suddenly has been reduced to a level below the threshold for the cones, and the rods, in their state of extreme light adaptation, are temporarily insensitive

Dark adaptation means the *increase in sensitivity* of the retina which occurs when light is either excluded from the eye altogether or is reduced to a very low level of intensity This type of adaptation is due primarily to changes in the rods After the cones have been responding to moderately intense illumination, removal of the light does not bring about any great increase in their sensitivity But rods which have been rendered almost wholly insensitive by the continued action of intense light then become dark adapted to such an extent that they acquire a sensitivity to light at least a thousand times greater than that of the cones The sensitivity of the rods is increased greatly within a few minutes after light has been excluded from the eye, but complete dark adaptation requires 30 minutes or more in normal individuals The effect of this kind of adaptation is shown by the invariably rapid recovery from the "blinding" which we experience when we enter a relatively dark place Although at first we can see very little (as a result of the previous light adaptation of the rods), soon we are able to perceive objects at least in outline, though not in color

3. Daylight "Blindness" in Animals Whose Retinas Contain Rods or Rodlike Cells Only. Various nocturnal animals, such as owls and bats, are known to have only rodlike cells in their retinas Such animals are "blind" under daylight conditions because their retinas contain no cones, and the rods become light adapted to such an extent that they are practically nonfunctional However, under conditions of very low illumination, these animals "see" extraordinarily well In fact, they are reputed to "see" in the dark As a matter of fact, no organism can "see" in absolute darkness What actually happens is that through dark adaptation the rodlike cells of their retinas become sufficiently sensitive to make "seeing" possible when only a very small amount of light is present Similarly, human individuals of the albino type, who also have retinas devoid of functional cones, see so poorly under daylight conditions that they can get about only with the aid of smoked glasses, which serve to reduce the intensity of illumination to such a low value that the rods may become dark adapted and therefore sensitive Albinos are also blind at the fovea, and are wholly unable to perceive colors

4. Achromatic Peripheral Vision in Daylight Illumination. Individuals possessing perfectly normal eyes are totally color blind in the extreme periphery of the retina This fact has been demonstrated in the following manner A small object of any color—red, green, yellow, blue, etc—is placed back of a subject's head While the subject continues to look fixedly straight ahead, the object is moved slowly around the side and toward the front of his head (by means of a special instrument, the *perimeter*) and the subject is instructed to report his first glimpse of it Under these conditions, the subject first sees the object when it is far out to the right (or left) of his line of vision, and from that position it appears to him to be almost or entirely colorless Apparently, the reason for its lack of color is that light reflected from the object at that point reaches only the extreme periphery of the retina where there are many rods, but few, if any, cones These observations suggest that the excitation of the cones is required for color vision, and that the rods are receptors for achromatic vision only

5. Achromatic Vision in Deep Twilight: The Photochromatic Interval. When the intensity of illumination is just at the absolute threshold of visibility, that is, when it is so low that objects can be

just barely perceived, everything seen appears to be black or gray If the intensity of the illumination is increased, the objects continue to appear gray until a certain critical intensity value is reached which is called the "chromatic threshold" From this point on, the objects are seen as colored The range of intensity values extending from the absolute visibility threshold to the "chromatic" or color threshold is known as the *photochromatic interval* These facts suggest that the retinal cells which function at low levels of illumination are insensitive to color, and that only those cells which function at higher levels of stimulus intensity are responsive to wave-length differences

6. The Absence of an Achromatic Threshold at the Fovea. However, at the fovea, where there are no rods, there is no photochromatic interval If light of a given wave length is of sufficient intensity to excite the cones of the fovea at all, the light is perceived at once as colored This fact indicates that under all conditions of illumination (save when the intensity is below their thresholds of sensitivity) the cones are sensitive to the wave-length character of light

7. The Purkinje Phenomenon. More than one hundred years ago, the Austrian physiologist, Purkinje, observed certain striking changes in the brightness relations among various colors when the intensity of illumination was reduced below the threshold for color vision The objects of his earliest observations were the colored figures of the carpet and of the hangings of his study. Under daylight conditions the yellow figures were the brightest of all, but under deep twilight conditions, when all the colored figures appeared as different shades of gray, the brightest gray figures were not those which had appeared as yellow figures under bright-light conditions, but rather those which had been seen as green Moreover, reds and blues no longer appeared equally bright as they had under daylight conditions, the gray figures which had been blue were much brighter than those which had been red In fact, in deep twilight the red figures became definitely black

Subsequently, several investigators obtained quantitative experimental data from which they constructed curves showing how luminosity (*i e*, apparent brightness) varies with the wave length of the light stimulus Brightness curves were plotted both for twilight and for bright-light vision These two curves were found to have the same form, but the curve for achromatic (*i e*, twilight) vision was

shifted somewhat toward the violet end of the spectrum, so that its maximal brightness was at about 520 mμ[1] (green) instead of at 560 mμ (greenish yellow) which is the maximum of the daylight curve

In terms of the duplicity theory, this change in the apparent brightness of lights of different wave lengths can be accounted for readily A decrease in the intensity of illumination to a value below the threshold of excitation of the cones causes the rods to become the sole functional receptors, and the relative brightness of lights of different wave lengths differs for the two types of retinal cells

All of the seven lines of evidence which we have described lend support to the von Kries duplicity theory of vision, according to which the rods and cones of the retina perform characteristically different functions in the process of seeing As an example of a quantitative experiment which has furnished data substantiating that theory, we shall review the study of Hecht and Williams

BRIGHTNESS CURVES FOR TWILIGHT AND DAYLIGHT VISION· THE FUNCTION OF VISUAL PURPLE[2]

The experiment of Hecht and Williams had a twofold purpose One aim was to make an exact quantitative study of the Purkinje phenomenon described above In order to do this the experimenters planned (1) to determine accurately the relative brightness of lights of different wave lengths (or frequencies) when viewed under conditions of dim-light vision, (2) to construct from these data a brightness curve for dim-light vision, and (3) to compare this curve with one similarly obtained for lights of different wave lengths under bright-light conditions

The second aim concerned the visual purple, a substance found in the rod cells When lights of very low intensity act upon the rods, they bring about chemical changes in the visual purple Hecht and Williams attempted (1) to determine the relative degree of bleaching effect which lights of different wave lengths exert upon the visual purple, and (2) to compare the curve which represents these effects

[1] The mμ (millimicron) unit is the one-millionth part of the millimeter, and is employed to measure the length of light waves The normal human eye responds to light stimulation over a wave length range of from about 390 mμ (violet) to 760 mμ (red)

[2] Adapted from Hecht, S, and R E Williams The Visibility of Monochromatic Radiation and the Absorption Spectrum of Visual Purple *Journal of General Physiology*, 1922 vol 5, pp 1-33

with the brightness curve for dim-light vision If the brightness curve for dim-light vision were found to coincide with the bleaching curve for visual purple, it might be concluded that visual purple is the active retinal photochemical substance in achromatic vision

METHOD

Subjects. The subjects were 48 graduate students and instructors at the University of Liverpool Their average age was twenty-five years Forty-three of them were men, five were women

Apparatus It was necessary, first of all, to obtain pure homogeneous moncohromatic lights, i e, lights which were of a single wave length To secure these homogeneous lights, white light from a 500-

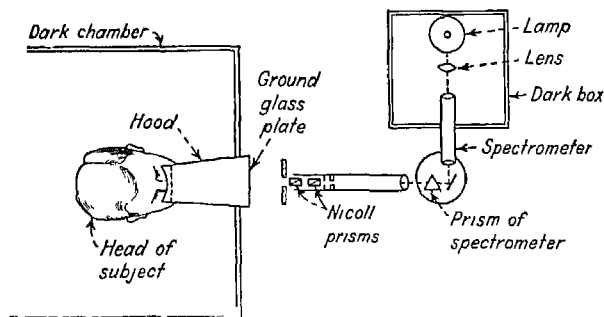



FIG 6 Diagram Showing Ground Plan of the Apparatus of Hecht and Williams

candle-power lamp was passed through a lens and then through a spectrometer White light is composed of lights of all the various spectral wave lengths Upon entering the glass prism of the spectrometer, the various wave-length components were refracted (bent) at different angles, and means were devised for selecting a beam of any desired wave length and diffusing it upon a ground-glass plate It was also necessary to regulate with precision the intensity of the homogeneous lights This was accomplished by having the beam pass through a pair of Nicol prisms By a change in the angle between the prisms the intensity of the light could be changed at will[1] A schematic representation of the entire apparatus is shown in Fig 6

[1] Measures of the relative intensities employed could easily be obtained, since the intensity of light transmitted by a pair of Nicol prisms is proportional to the square of the cosine of the angle between the prisms

As was stated above, the monochromatic light was diffused upon a ground-glass plate This plate formed the back wall of an observation box into which the subject looked through a hooded window Upon the inner surface of this plate (i e, the surface nearest the subject's eye) an oval figure was drawn in opaque radium paint (see Fig 7) This figure constituted a constant visual stimulus, of an intensity which was above the absolute threshold of visibility but well below the threshold of color The area covered by the oval figure was not completely painted Instead, sections shown in black in Fig 7 were left unpainted on the ground glass, which allowed light from the spectrometer to show through

FIG 7 Oval Figure Which the Subject Observed on the Ground Glass Screen

The white portion of the figure is radium paint, the dark part is where the light from the spectrometer shows through When a perfect match for brightness is obtained, the dark portions of the figure disappear entirely, and the entire oval appears uniform in brightness

Procedure The subject was brought into the dark room and was fully informed concerning the object of the experiment, the apparatus, and the procedure He was then seated in a curtained-off dark chamber, facing the oval window of the observation box described above Light from the spectrometer was cut off, and at least one-half hour was allowed for the subject's eyes to become adapted to the darkness During this time, the subject was able to watch and follow closely the gradual appearance of the radium-painted figure, which became progressively clearer as a result of the increasing sensitivity of his eyes The figure usually became faintly visible after the first 10 or 15 min, and increased in brightness and clearness during the next 15 min, so that the subject soon became familiar with its shape After about 30 min, the places at which the light from the spectrometer would later come through the ground-glass plate appeared as dark bars on a moderately bright background

At the end of the adaptation period, the experimenter introduced a few practice trials in which light with a wave length of 412 mμ (violet, under bright light conditions) was projected upon the ground glass plate from the spectrometer The light at first was made very weak, then its intensity was increased by small steps until the subject reported that the dark bars mentioned above had disappeared The disappearance of these bars meant that their brightness had come to

match precisely the brightness of the radium figure Every time such a match was made, the intensity value of the light required to produce the match was recorded. By the time the practice tests had ended, the subject had been in the dark chamber at least 45 min, a period which was sufficiently long to bring about complete dark adaptation Then the same procedure was used to obtain brightness matches between the luminous figure and each of the following wave lengths 412, 455, 486, 496, 507, 518, 529, 540, 550, 582, 613, and 666 mμ[1] In order to test the reliability of the method, a final trial was made at the end of this series with wave length 412 mμ, the wave length used at the beginning of the experimental series Another test of reliability consisted of having some of the subjects return to the laboratory for retests at later dates Since all these retests gave similar results, the reliability of the method was confirmed

RESULTS

For each subject a curve was plotted to show the particular intensity at which each given wave length exactly matched the brightness of the radium figure As Fig 8 shows, these curves were U-shaped Hence, relatively great light intensities were required to match the standard radium stimulus when the wave lengths were from points near the two ends of the spectrum, and relatively little energy was required when wave lengths from the middle region of the spectrum were employed The least intensity of all was required for light of wave length 511 mμ (which is green in daylight vision)[2]

[1] The hues which, in chromatic vision, correspond to these wave lengths are the following

Wave length, mμ	Hue	Wave length, mμ	Hue
412	Violet	529	Green
455	Blue	540	Yellow-green
486	Blue	550	Yellow-green
496	Blue-green	582	Yellow
507	Green	613	Orange
518	Green	666	Red

[2] In plotting these curves, the *logarithms* of the intensity values were plotted against

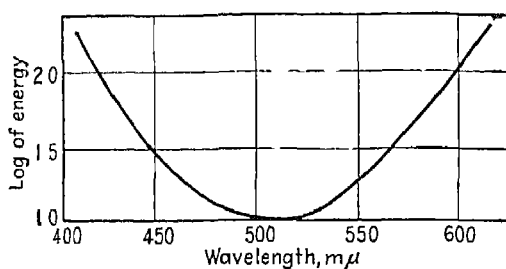



Fig. 8 Curve Showing Relationship between Wave Length and the Light Intensity Required to Produce a Brightness Match with the Standard Radium Stimulus (*After Hecht and Williams*)

Table I

Showing, for the Different Wave Lengths Used, (1) the Relative Intensities of Light Required to Match the Standard Radium Stimulus, and (2) the Relative Visibility Values of These Wave Lengths under Dim-light Conditions at a Constant Level of Energy, i.e., Intensity

Wave length, mμ	Color produced in bright-light vision	(1) Relative intensity	(2) Relative visibility
412	Violet	158.10	6.32
455	Blue	25.03	39.95
486	Blue	11.99	83.40
496	Blue-green	10.65	93.90
507	Green	10.06	99.35
518	Green	10.28	97.30
529	Green	10.98	91.10
540	Yellow-green	12.69	78.78
550	Yellow-green	17.99	55.60
582	Yellow	56.24	17.78
613	Orange	367.20	2.72
666	Red	5525.00	0.181

By a statistical procedure which need not be described here, the data for all the subjects were combined, and the average relative intensities required for the several different wave lengths were calculated. These averages are given in column 3 of Table I.

the wave length values, since a direct plot covering so large a range of values would have served to minimize the finer changes which occur at the lower intensities and to exaggerate the larger changes at the higher intensity levels.

The values given for the various wave lengths in column 3 represent the relative intensity of light which was required to produce a given, constant retinal effect (*i e*, to match the radium figure in brightness) The reciprocals of these values represent the relative stimulating effects of the different wave lengths with the energy factor held constant These reciprocals, multiplied by 1,000, are entered in column 4 of Table I A curve plotted for these reciprocal values resembles in form the "normal" or Gaussian probability curve

Upon the same axes, Hecht also plotted a curve based upon data obtained by other investigators who used techniques similar to his own, but who worked with intensities of the standard stimulus which

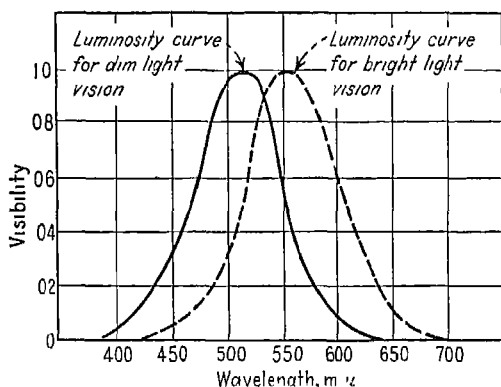



Fig 9 Luminosity Curves for Dim-Light and Bright-light Vision (*After Hecht and Williams*)

were above the color threshold (*i e*, under bright-light conditions) It can be seen in Fig 9 that the luminosity (or brightness) curve for bright-light (chromatic) vision has the same form as that for dim-light (achromatic) vision, but that the point of maximum brightness for the latter condition is shifted about 48 mμ toward the violet end (*i e*, the short-wave end) of the spectrum Hence, these curves provide a quantitative representation of the change in brightness relations as the transition is made from daylight vision to twilight vision The change as described from this study is precisely that which was more crudely described by Purkinje many years ago

As we have said, the fact that a shift in the relative brightness of lights of different wave lengths occurs when the intensity of illumina-

tion is reduced below a certain level may be interpreted as constituting additional evidence in support of the duplicity theory It is highly probable that the luminosity curve for dim-light vision is the curve of sensitivity of the rods, whereas the curve based upon data obtained under daylight conditions is the sensitivity curve of the cones If this be true, then the same wave lengths differ in their relative stimulative effects upon the rods and the cones At low, constant intensities light of wave length 511 mμ (green) has the maximum stimulating effect upon the rods, whereas at higher constant intensities it is light of 559 mμ (yellow) that has the maximum effect upon the cones (provided, that is, the intensity factor is held constant) The longest waves of the visible spectrum, those which range from 650 to 760 mμ and which appear as red under bright-light conditions, can excite the cones only if their intensity is relatively high, if their intensity is low, they have no appreciable effect upon either type of receptor cell

Achromatic Vision and Visual Purple

Is visual purple the active photochemical substance in the rods of the retina? That is to say, is visual purple the substance which is chemically altered by light and which thereupon initiates the process of excitation in the retinal neurones associated with the rods? An attempt was made to answer this question by comparing the luminosity curve for achromatic vision with the curve representing differences in the action of lights of different wave lengths upon visual purple Visual purple which has been extracted from the retina retains its purplish color only so long as it is shielded from light When it is exposed to light, it loses its color, *i e*, it is bleached, but the velocity of this bleaching response differs for lights of different wave lengths, when the intensity of the lights is held constant [1] Hecht and Williams determined as accurately as possible the times required for lights of the different wave lengths to produce the same bleaching effects They found that bleaching times were far longer for violet and red, extreme red having scarcely any bleaching effect at all They then converted their measurements into values which were comparable with the relative wave-length brightness values upon which their luminosity curves had been constructed Comparison of

[1] Although bleached by light, visual purple regains its former hue when it is removed to a dark place

the curve which represented the bleaching effects of different wave lengths with the luminosity curve for achromatic vision showed that the two curves were very nearly identical The two curves did not coincide perfectly, but the amount of divergence was well within the limits of experimental error The almost complete identity of the two curves lends further support to the view that the visual purple associated with the rods of the retina *is* an active photochemical substance

If the visual purple is the photochemical substance associated with the rods, it might be inferred that the cones must contain a similar photochemical substance, since the luminosity curves for rod vision and for cone vision, although they do not coincide, are identical in form In this connection, Hecht suggests two possibilities (1) that the visual purple of the rods and the hypothetical photochemical substance of the cones may be two different, although closely related, substances, or (2) that the visual purple may exist in both the rods and the cones, but in media (or solvents) of different density It has been shown that when a given substance which absorbs light is dissolved in different media its absorption curve shifts Such a substance could well give luminosity curves 48 mμ apart, if it were dissolved in media which differed in density and refractive power

Discussion

Many of the facts and principles of retinal functioning which we have reviewed in this chapter acquired new significance during the Second World War, when they were applied in various useful ways both in the armed services and in civilian defense organizations

One example of such application is that air-raid wardens who were trained to serve as observers under black-out or similar dark conditions were advised to try to identify an obscure object by "looking past" it instead of directly at it Another example is the decision that red was the safest color of filter for an air-raid warden to place over the lens of his flashlight It could be assumed that the eyes of an observer in an enemy plane would be dark adapted, and that his vision would be dependent upon the rod cells of his retinas As we have seen, it has been established that the rods are least responsive to the long waves of the red band of the spectrum Hence red would be the color of light least detectable by a plane flying at night overhead

A further application of the fact that the rods do not respond to red light was the use of red goggles to facilitate the dark-adaptation process An observer who is to stand watch in a black-out situation (*e g* , an aerial observer) must allow his retinas to become completely dark adapted, a process requiring 30 min or more By wearing red goggles, such an observer was able to spend a considerable part of the adaptation period in a normally illuminated room engaged in useful work instead of having to spend all of it in a dark room doing nothing The reason for the efficacy of the red goggles is that red glass absorbs all the shorter wave-length components of white light and transmits to the eyes only the long red rays Since the red rays do not excite the rods, the observer was able to enjoy modified cone vision while the rods became dark adapted

Also of interest in this connection is the method employed to simulate night flying conditions in daylight during the training of airplane pilots The windshield and windows of the cabin of the plane were coated with green acetate, and the pilot-trainee wore red goggles The green acetate absorbed long and short waves, but allowed light of medium wave-length values in the green region of the spectrum to pass through it Since most of this green light was absorbed by the red-goggle lenses, the world outside the cabin appeared dark to the pilot However, he was able to see the lighted instruments inside the cabin, although they appeared reddish to him The instructor, who wore no colored goggles, saw the instruments normally and had an adequate view outside the plane, although for him everything outside was tinted green

Illustrations such as those above show that many of the experimentally determined facts concerning human vision and their interpretation in the light of the duplicity theory are far from being of academic interest only Similarly, data concerning the visual purple can easily be shown to be relevant to everyday problems of human adjustment An individual is often called upon to adjust visually under rapidly changing intensities of illumination Suppose, for example, that a person is driving a motor car at night If his eyes have been stimulated by bright headlights and the intensity of illumination suddenly falls to a low level, some dark adaptation of the rods must occur without too much delay if the driver is to avoid accident Individuals differ greatly in the speed with which their retinas become

dark adapted, in the so-called "night-blind" individual this process requires an abnormally long time Obviously night blindness makes night driving hazardous The possession of good daytime vision (*i e* , cone vision) is no guarantee that the individual will be able to adjust adequately under night conditions

The speed at which dark adaptation occurs apparently depends upon the velocity with which the visual purple recovers after it has been acted upon and modified (and, incidentally, bleached) by light It has been known for several years that visual purple is rich in vitamin A, the fat-soluble vitamin found in cod-liver oil, halibut-liver oil, and certain vegetables, notably carrots Visual purple which is deficient in this vitamin shows an exceptionally long recovery time after exposure to light Experimental results demonstrate that animals which have been deprived of vitamin A become "night blind," but that they recover their normal nocturnal vision after vitamin A has been restored to their diet It has also been found that the administration of this vitamin in large amounts induces a more rapid dark adaptation in "night-blind" human subjects Hence the adaptometer (an instrument employed to determine precisely the time required for dark adaptation) is used by some diagnosticians to detect and to estimate the magnitude of vitamin A deficiency in the diet If adaptometer tests reveal an abnormally long adaptation time, it is concluded that the subject's diet has been deficient in vitamin A

It is believed that a riboflavin (vitamin B_2) deficiency is also related to a slow dark-adaptation rate and to night blindness Furthermore, there is evidence that the behavior of the visual purple is dependent upon the physiological condition of various organs of the body For example, 96 per cent of a group of people suffering from kidney stones and 95 per cent of a group suffering from a liver disorder were found to be "night blind" There are also indications that many people adapt very slowly to darkness when they have severe colds, sinus infections, and the like These disorders may be related to vitamin deficiencies or to disturbances in the metabolism of these vitamins

In conclusion it is fitting that we call attention to the greatly increased interest among psychologists in problems relating to sensitivity This interest developed during the war largely because of the urgent need for new devices to improve the accuracy of visual and auditory observation, and to test the sensory capacities of the

men and women in the armed services It also became important to identify the significant sensory cues controlling the activities of pilots and bombardiers and of observers of many types, since with increased knowledge of these sensory cues, more adequate training methods might be devised

Among the many specific problems with which experimental psychologists became concerned during the war years were problems of visual organization, especially as related to the determination of the effectiveness of camouflage, problems of color perception and the extent to which the different varieties of color blindness might handicap men in specific branches of the service,[1] the investigation of the acuity of peripheral vision, and the development of possible methods for improving the accuracy of peripheral visual perception, studies of the visual cues made use of in landing a plane, with a view toward reducing the frequency of landing accidents, the determination of the optimal design of instrument dials and the optimal arrangement of instruments on the plane's instrument panel from the standpoint of quick and accurate visual perception, studies of the effect of oxygen deprivation at high altitudes upon dark adaptation, visual acuity, and the speed and coordination of eye movements Worth noting is the fact that in the investigations on oxygen deprivation it was found that such deprivation brings about a lengthening of dark-adaptation time, a pronounced diminution in visual acuity, and a marked disorganization of the eye movements involved in reading instruments, examining maps, charts and the like

Related to these problems are numerous others involving complex perceptual processes, of which the perception of the vertical discussed in Chap XXI is an example

Consideration of such applications as have been mentioned above shows that the facts and theories of human sensitivity, despite their technical difficulty and their apparent abstruseness, are among the most important in psychology from the viewpoint of direct practical usefulness

[1] It was discovered that persons afflicted with one variety of partial color blindness made valuable contributions as aerial observers, since they could detect certain modes of camouflage that were likely to go unnoticed by the normal observer

CHAPTER IX

THE PERCEPTION OF OBSTACLES BY THE BLIND

Introduction

The remarkable and highly complex capacity of spatial orientation, that is, of finding one's way and maintaining a position with reference to surrounding objects, ordinarily is taken for granted by most people, including even students of psychology The predominant and intricately organized role of visual sensitivity in spatial orientation is appreciated by few of the sighted individuals who depend upon it constantly in their everyday activities, although to scientific specialists the analysis of these visual abilities represents one of the most interesting and difficult problems in the field of space perception [1, 2]

When the normal-sighted individual must find his way and avoid obstacles in the dark, without a light and solely by nonvisual cues, his blundering inept movements stand in sharp contrast to the efficiency and precision of his orientation in the light and emphasize the extent to which his everyday activities depend upon visual stimuli from the surrounding environment This contrast makes us wonder at the dexterity with which most blind individuals habitually make their way about in total darkness

This capacity which the blind demonstrate strongly suggests the existence of environmental cues (*i e* , potentially useful stimuli) other than visual ones which can adequately guide one's spatial orientation when vision is not available It is evident that these cues, whatever they may be, are not effectively employed by most sighted individuals, who are very unskilled at avoiding objects in pitch dark or when blindfolded On the other hand, they must be utilized by blind individuals who commonly detect and avoid obstacles readily without the aid of vision

Such comparisons have led to much speculation about the nature of the spatial orientation of the blind, the ways in which their accom-

[1] Carr, Harvey *An Introduction to Space Perception* New York, Longmans, 1935

[2] Werner, H Dynamics in Binocular Depth Perception *Psychological Monographs*, 1937, No 218

plishments in orientation differ from those of sighted individuals, and whether such abilities can be acquired through long practice, as they seem to be by people who have lacked sight from birth or from the early years of life

There have been many attempts to find a solution for these problems For example, as long ago as 1747 the French scholar Diderot reported the "amazing ability" of a blind acquaintance both to perceive obstacles in his path and to judge their distance from him Diderot advanced the idea that the action of air on the subject's face as he moved about somehow permitted him to localize and avoid obstacles, in other words, that the blind literally use their cheeks and foreheads as "feelers" This was an early specific form of what became a favorite general theory of many writers and investigators, namely a *sensory* type of explanation According to this view, the blind avoid obstacles through the heightened responses of known sense organs, *e g*, through the action of air pressure and air currents (as reflected from objects in the environment) on the cutaneous nerve endings of exposed skin, through auditory sensitivity proper, or through pressure or similar nonauditory effects on the tympanic membranes and other structures of the ears This sensory hypothesis has been extended to include a *perceptual* process, through which blind individuals not only receive sensory cues to which sighted persons are usually not responsive, but also "interpret" and use them in special organized ways There also has been advanced an *occult* (*i e*, mystical) hypothesis, according to which the blind person is assumed to possess a "sixth sense" different in nature from any sense yet known, to rely on such purely conjectural agents as magnetism and vibrations of "ether" or even on some assumed action of the "unconscious"

Prior to the experiments to be reported in the present chapter, the literature on this subject presented a rather confused picture which afforded no basis for determining which of the above possibilities (or which combination of them) might be correct Some of the earlier investigators had concentrated upon one possible explanation and some upon another, with corresponding differences in their methods, but no thoroughgoing experiments had been conducted involving the adequate control of all possibilities in the same set of tests One experimenter, Villey[1], supplemented his tests of blind soldiers with

[1] Villey, P *The World of the Blind* (*A Psychological Study*) London, Duckworth, 1930

a series of questions designed to discover how they thought they avoided obstacles. One-fourth of the men interviewed thought they used hearing, one-fourth thought they used contact in some way, and the remainder attributed their avoidance of obstacles to a combination of these It is clear that a problem such as this can be solved only by adequately designed experiments

The experiments to be reported in the present chapter were directed toward answering questions such as those discussed above They are described here in considerable detail, not only because they represent an attack upon a problem which has long interested students of human behavior, but also because they provide an impressive example of how the investigation of such a problem may be undertaken by means of an appropriately planned series of controlled experiments

THE CORNELL EXPERIMENTS ON OBSTACLE-LOCATION BY BLIND AND SIGHTED SUBJECTS

GENERAL PLAN

Three principal investigations were carried out The first of these consisted of seven experiments designed to explore the nature of ob stacle avoidance under different conditions by sightless individuals The plan was to make a thoroughgoing study of the performance of blind subjects in avoiding a test obstacle, and to compare their ability with that of blindfolded sighted subjects The object was to ascertain what factors are involved in the avoidance of obstacles by blind individuals, and whether sighted individuals can acquire such abilities, at least to some extent, through practice In the second and third investigations, several deaf-and-blind subjects were used in further controlled experiments directed at a more precise isolation of the factors governing obstacle-avoidance by blind persons

First Investigation. Obstacle Location in Blind and in Blindfolded Seeing Subjects[1]

In the experiments of the first investigation, all the subjects were blindfolded throughout The first tests were conducted under conditions normal to the blind These initial tests were exploratory, and their object was to compare the degree of skill of the blind and

[1] Adapted from Supa, M , M Cotzin, and K M Dallenbach "Facial Vision", the Perception of Obstacles by the Blind *American Journal of Psychology*, 1944, vol 57, pp 133–183

normal subjects[1] (*i e*, to ascertain their standard performances) under a few simple variations of the experimental conditions

SUBJECTS AND SITUATION

Four subjects served throughout all seven experiments of the first investigation Two of them had normal vision and two had been blind from early life The blind subjects were Mr E S, an undergraduate student twenty years of age who had lost his vision when five years old, and Mr M S (one of the authors), twenty-two years of age and a graduate student in psychology, who had lost his effective vision at about twenty months of age, except for a slight sensitivity to light in the left eye The normal subjects were Miss P C and Mr J D, both graduate students in psychology Both blind subjects exhibited in their daily behavior a notable ability to perceive obstacles from a distance This ability was attributed by M S to audition, E S, on the other hand, thought that sounds were a hindrance and that reactions to air currents acting on his face accounted for his successful space perception At the beginning of the experiments neither of the normal subjects could detect distant obstacles when blindfolded, and walked directly into objects in their path

All seven experiments in the first investigation were performed in the large hall of the graduate psychology laboratory at Cornell University (except for Experiment IV in which a soundproof room was also used) This hall is 18 ft wide, 61 ft long, and 20 ft high, with a beamed, center-ridged ceiling and skylights There are seven doors on each side of the hall, together with two doors and a descending stairway with open stair well at one end, and one door near a side of the opposite end During the experiments, all the doors were closed, small apparatus and movable furniture were placed out of the way at the unused (stairway) end of the hall, and only glass-door apparatus cases and larger pieces of apparatus were left standing along each side wall

GENERAL METHOD AND PROCEDURE

The eyes of blind and normal subjects alike were covered with cotton pads, and a flexible leather blindfold was fitted snugly over

[1] The fully visioned subjects in this investigation will be referred to as the "normal" subjects, as distinguished from the blind subjects Both sighted and blind subjects wore blindfolds in all the experiments

the forehead, around the temples, and over the cheeks Thus all the subjects were "blind" and had their exposed facial areas reduced by like amounts In all experiments the subjects were tested separately

In the first six experiments, each "trial" was conducted in the following manner The subject was started at a predetermined distance from the obstacle with instructions to walk toward it, to stop and raise his right arm when he first perceived the obstacle (the *distance perception*), and then at a verbal signal from the experimenter to approach as near as possible to the obstacle without touching it, indicating when this point (the *close perception*) was reached by raising his left arm In each trial, those two distances were recorded by the experimenter to the nearest 6-in interval by means of a tape measure stretched taut on the floor in the subject's path A further measure of performance was obtained by recording the number of actual collisions with the obstacle made by each subject

In Experiments I and VII the obstacle was the end wall of the hall opposite the stairway, a stone wall which reflected air and sound waves very efficiently by virtue of its hard-plastered surface covered with semigloss paint In Experiments II to VI, inclusive, the obstacle was a piece of masonite board[1] 1/2 in thick, 4 ft wide and 4 ft 10 in high, mounted on a portable stand so that its lower edge was 2 ft from the floor and its upper edge was at a height (6 ft 10 in above the floor) well above the elevation of the subject's ears

Experiments I to V, inclusive, were carried out under each of two conditions in *condition A* the subject wore shoes and walked on the hardwood floor toward the obstacle, guided by two narrow carpet runners which kept him in a lane 2 ft wide between them In *condition B* the subject walked toward the obstacle in his stocking feet and was guided by having to keep on a soft carpet runner 30 in wide and 40 ft long [2] The progress of the subject under conditions A and B is represented in Fig 10 These two conditions were counter-

[1] Masonite (a composition board) proved to be the most satisfactory of all the surfaces tried The subjects readily detected plywood boards, whether unfinished or finished with shellac, varnish, paint, or wax, through their odors at a distance Masonite, however, furnished no cues of an olfactory type

[2] The carpet guide was not used in Experiment IA Instead, the subject was guided when necessary by means of appropriate hand taps by the experimenter on his shoulder, as explained below

balanced in the five experiments by having condition A precede B in Experiments I, III, and V, and follow B in Experiments II and IV. Under each condition the trials were continued until a subject had achieved 25 "successes," that is, had approached the obstacle closely twenty-five times without colliding with it Further information

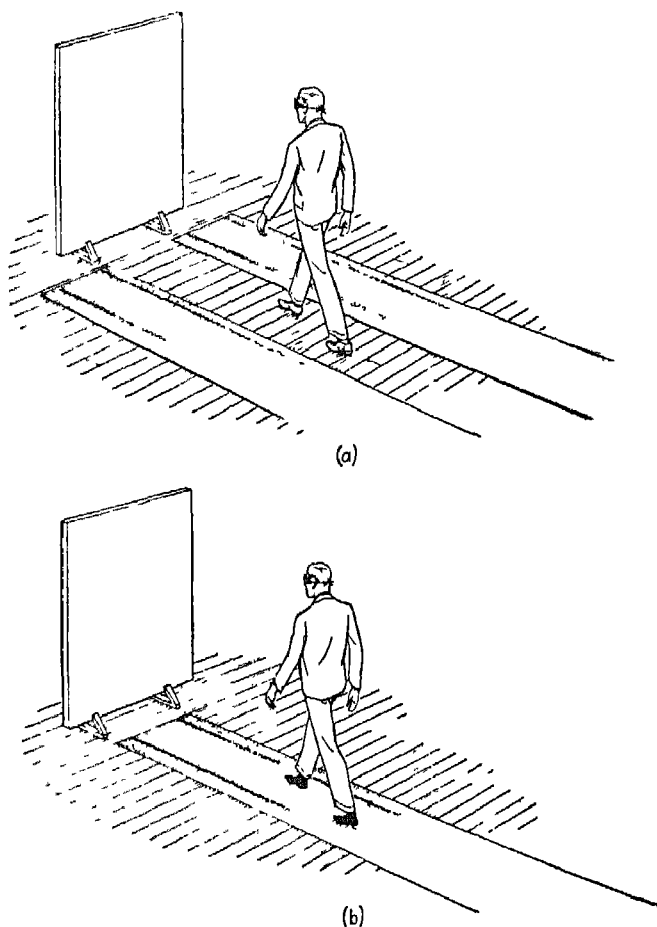



FIG 10 Tests in Obstacle Perception Experiment II

10a The subject approaching the obstacle (a masonite screen) under condition A in Experiment II, walking with shoes on the hardwood floor and guided toward the obstacle by the lane between two carpet runners

10b The subject approaching the obstacle under condition B in Experiment II, walking in stocking feet on a carpet runner which serves to guide him toward the obstacle

about method and procedure is given in connection with the description of each individual experiment

PRELIMINARY EXPERIMENTS (I–III)

Experiment I, Condition A. The initial exploratory tests were made as favorable as possible for the perception of obstacles without the use of vision The subject wore shoes, walked on the hardwood floor toward the reflective end wall, and was permitted to make as much noise in walking (*e g* , by shuffling his feet) as he wished The subject was first led around the hall for 3 minutes to disorient him, then was started toward the wall from distances of 6, 12, 18, 24, or 36 ft , in a prearranged haphazard order on successive trials In Experiment I, condition A differed from the corresponding condition in the other experiments in that the two carpets and the lane between them were not used Instead, the subject was kept going straight toward the obstacle by appropriate taps on the right or left shoulder delivered by the experimenter whenever the subject deviated from a direct line

Results The blind subjects were successful on every one of 25 consecutive trials, and therefore were given no further tests under condition IA They stepped out unhesitantly, required no guidance to approach the wall directly, and did not walk into the end wall a single time M S , who stepped heavily and clicked his heels on the floor as he walked, reported that he "listened" for reflected sounds E S , who performed best of all four subjects, walked quietly, and reported using cutaneous cues (*e g* , air currents?), which he localized in his forehead

The sighted subjects, in contrast to the blind subjects, required many more than 25 trials in order to achieve 25 successes P C needed 40 trials, and J D , 44 Their advance was hesitant, their step shuffling and noisy Without any guidance, they would have walked repeatedly into the side walls of the hall At first they collided constantly with the end wall, however, after a few trials—eight for P C and nine for J D —they began to have some success In a second practice series under condition IA, P C collided with the end wall only six times as against fifteen in the first series, and J D only once as against nineteen times in the first series

A comparison of the results for the four subjects, in Table I, shows

Table I

The Average Distance and the Mean Variation (in Feet) of Distance Perceptions and Close Perceptions of the Experimental Obstacle by Blind and Normal Subjects under Conditions A and B, Experiments I to VII, also the Number of Collisions with the Obstacle in Each Series

(D P, Distance Perception, C-P, Close Perception, Coll, Collisions, MV, Mean Variation[1])

Experiment and series		Subjects							
		E S (blind)		M S (blind)		P C (normal)		J D (normal)	
		Score	MV	Score	MV	Score	MV	Score	MV
I Wall as obstacle									
A Shoes on hard floor	D P	18 04	±6 69	6 36	± 64	2 12	± 80	0 98	± 80
	C P	52	± 04	54	± 07	56	± 10	56	± 11
	Coll	0		0		15		19	
B No shoes, on carpet	D P	17 88	±7 17	3 46	±1 56	4 70	±3 38	1 18	± 46
	C-P	62	± 19	72	± 28	1 08	± 51	88	± 18
	Coll	2		4		4		6	
Repetition, Series I-A	D P			6 08	± 92	2 58	±1 20	93	± 36
	C P			50	± 09	68	± 26	77	± 17
	Coll	0		0		6		1	
II Screen as obstacle									
A Shoes on hard floor	D P	15 60	±5 54	3 70	±1 50	3 22	±1 29	2 98	±2 50
	C P	58	± 13	74	± 27	62	± 20	94	± 70
	Coll	0		1		3		7	
B No shoes, on carpet	D P	13 62	±7 72	4 88	±3 25	4 54	±2 74	1 50	± 68
	C P	1 10	± 80	2 86	±3 19	1 20	± 71	66	± 24
	Coll	4		4		3		15	
III Screen									
A Same as II A	D-P	17 08	±6 96	3 98	±1 18	3 34	±2 13	3 20	±1 70
	C P	50	± 00	58	± 14	84	± 34	00	± 27
	Coll	0		5		1		1	
B Same as II B (no shoes, on thick carpet)	D P	8 16	±5 58	2 58	±1 03	1 05	± 36	1 72	±1 33
	C P	50	± 00	54	± 07	50	± 00	52	± 04
	Coll	1		3		1		1	
IV Screen									
A Same as III A except for felt head cover etc	D-P	8 56	±1 94	7 44	±2 01	1 44	± 81	3 64	±1 67
	C P	62	± 18	56	± 11	70	± 30	1 00	± 85
	Coll	0		1		5		2	
B Same as III B except for felt head cover, etc	D P	4 88	±2 37	3 50	±1 08	1 64	±1 21	2 06	± 54
	C-P	62	± 22	64	± 20	66	± 22	78	± 29
	Coll	3		7		2		2	
V Screen									
A Same as III A except for ear plugs and cover	D P	0		0		0		0	
	C P	0		0		0		0	
	Coll	100[2]		100[2]		100[2]		100[2]	
VI Screen—Masking tone									
A Same as III A except for masking tone	D-P	0		0		0		0	
	C-P	0		0		0		0	
	Coll	100[2]		100[2]		100[2]		100[2]	
VII Subject hears over phone									
A series only	D P	10 20	±1 12	6 04	±1 80	6 60	±2 77	2 92	±1 09
	C P	2 74	± 34	94	± 46	1 60	± 24	82	± 35
	Coll	1		2		3		4	

[1] The mean variation is computed by obtaining the deviation of every individual score from the average or other measure of central tendency), then finding the average of these deviations

[2] Collision on every trial (no successful perceptions of obstacle)

that the blind subjects were clearly superior to the normal subjects in their *distance perception* of the wall Although the average distance of the *close perception* of the two groups was not different in the 25 successful trials, it must be remembered that the blind subjects had no collisions with the wall, whereas the normal subjects had 15 and 19 collisions, respectively, and so required many more trials to attain their 25 successes

A comparison of the mean variations of sighted and blind subjects shows that on the whole the latter were less variable One significant difference was that whereas both the normal subjects were thoroughly disoriented by being led circuitously around the hall before each trial, and needed guidance in approaching the obstacle, the blind subjects did not need guidance and could determine their approximate starting positions by reference to their perception of irregularities in the floor and of objects such as apparatus cases at the sides of the hall

Experiment I, Condition B. In this series, the subject walked in stocking feet upon the long carpet runner toward the obstacle wall The carpet both deadened the sound of the subject's footsteps and guided him toward the wall, a means used instead of shoulder taps to direct him to the obstacle in a straight line Otherwise, the procedure was the same as in IA

Results As Table I shows, the efficiency of the blind subjects was less than it had been under condition IA Their average distance-perception scores were lower (*i e* , they needed to walk closer to the wall for their initial perception of it), and their close-perception scores were higher (*i e* , they could not approach the wall so closely without collision) Both blind subjects had a few collisions with the wall, and their variability was greater than under condition IA It was observed that M S now walked with his head turned to one side as if to aid hearing It seems likely that his losses, as well as those of E S , are to be attributed to the reduction of auditory cues, although E S said he was pleased by the absence of "distracting noise"

Like the blind subjects, the two normal subjects were less efficient in close perception and exhibited a marked increase in variability Presumably their limited gains in the distance-perception scores were attributable to the practice in condition IA, and their losses in the close-perception scores to a decrease in auditory stimulation Both subjects appeared to "miss" the auditory cues that had been present

in I A P C shuffled her feet "to make some noise," and J.D found the trips harder because "there were no sounds upon which to base my judgments"

Experiment II After the normal subjects had learned to some extent how to perceive obstacles in the absence of visual stimuli and the blind subjects had become accustomed to experimental controls under conditions approximately normal for them, the masonite screen was used instead of the wall as the obstacle With the screen in different positions on successive trials the blind subjects were deprived of the advantage of their "absolute orientation" in the hall[1] To prevent the subject from confusing the screen with the wall, he was started at a fixed point near the wall and the screen was placed near the center of the hall at one of the predetermined distances of 6 to 36 ft These distances were used in variable order on successive trials Under condition A, as in all the experiments except I, the subject walked with shoes on the wooden floor in a lane between two carpet runners, and under condition B he walked in stocking feet upon the single carpet runner Before every trial, the subject waited outside the hall while the obstacle-screen and the lane were arranged, then he was led to the starting point, without knowledge of the position of the obstacle in the room Started by a tap on the back, the subject walked toward the obstacle without guidance except from the "lane" (condition A) or the single runner (condition B), indicating his distance perception and close perception of the obstacle as before by making the appropriate hand signals

Results All of the subjects were usually able to perceive the obstacle at a distance and to approach close to it without collision, despite its smaller size and its variable position in the hall However, a comparison of the results of Experiments I and II shows that the new conditions usually did have an adverse effect, especially on the blind subjects In the normal subjects, this effect seems to have been largely neutralized by continuing improvement due to practice E S again gave the best performance of the four subjects[2] M S ,

[1] Circumstances indicated that this capacity for placing themselves accurately or judging their general position anywhere in a room was attributable to long experience in spatial orientation before the experiments began

[2] In view of the fact that he was able to perceive the obstacle at the starting position of the three shorter distances (*i e* , 6, 12, and 18 ft) the results for E S in the table should be corrected by taking only the data for starts at 24 and 30 ft from the obstacle Thus

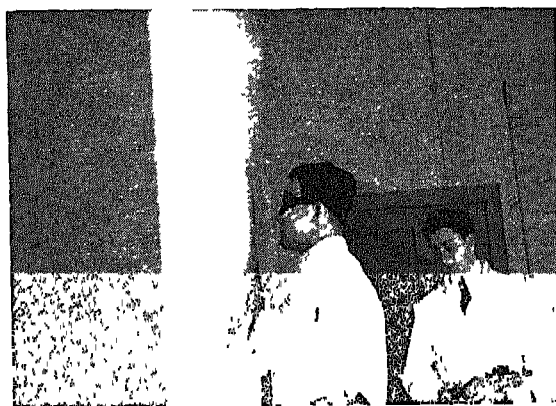
11*a*.

11*b*

FIG 11 Tests in Obstacle Perception Experiment III

11*a* The subject, approaching the obstacle in Experiment III, condition A, signals his distance perception of the screen by raising his right arm

11*b* The subject, approaching the obstacle in Experiment III, condition B, signals his close perception of the screen by raising his left arm

who seemed to lose proportionally more of his skill under the new conditions than did E S , now did only slightly better than the normal subject P C in distance perception, and actually fell slightly below

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corrected, the averages for his distance perception of the obstacle become 23 20 ± 3 41 ft in series IIA and 21 42 ± 4 84 ft in series IIB This correction is not necessary for the other subjects, since they did not perceive the obstacle at any distance until after they had started toward it

P C 's score for the close perception on series IIA and below that for both normal subjects in IIB

Experiment III. The two conditions, A and B, were again employed, but under condition IIIB the carpet runner was twice as thick as the one used previously Also, in this experiment, the subject was started on each trial from a different one of five positions (0–12 ft from the end of the room), instead of starting from a fixed position as in Experiment II As before, the screen was set at one of five distances from the subject's starting position, except that at random intervals a check trial was introduced in which no screen was used The result was that the positions of both subject and obstacle were changed on each trial The circumstances of conditions A and B in this experiment are shown in Fig 11

Results As the results summarized in Table I indicate, all of the subjects were still able to perceive the obstacle at a distance and to approach close to it with very infrequent collisions The blind subjects, particularly E S, were superior in almost all respects to the normal subjects in both series of the experiment [1]

The subjects were evidently disturbed in their distance perception of the obstacle by the thick carpet runner, since the distance-perception scores of all except J D were poorer than in Experiment IIB However, for all four subjects the close-perception scores were better, their mean variations were smaller, and they had fewer collisions than in IIB It is possible, however, that with the thicker carpet the subjects were forced to make more sound themselves and to listen somewhat more attentively than in Experiment IIB, for all of them now shuffled and scraped their feet continuously in approaching the obstacle

Discussion of Results, Experiments I–III. It is not surprising that the blind subjects from the beginning displayed to a high degree the ability to perceive objects at a distance and to avoid collisions with them, considering that they brought to the experiment the advantage of long experience A comparison of the results of the different tests reveals that the skill of the blind subjects dropped sharply under both conditions A and B when they passed from Experiment I, in

[1] When the scores of E S are corrected as before for immediate perception of the obstacle at the starting point, his distance perception averages improve to 23 6 ± 3 2 ft in III A and 9 13 ± 4 08 ft in IIIB

which conditions were similar to their everyday problems in orientation, to the more artificial and controlled situations of Experiment II. However, that they could still benefit from practice is suggested by the fact that even under the more restrictive conditions of Experiment IIIB their close-perception scores were better and their collisions fewer than under the B condition in Experiments I and II.

Although the normal subjects at first did not possess to any appreciable extent the ability to perceive distant objects without the use of vision, they rapidly acquired it under the favorable conditions of Experiment I, condition A. For them, in contrast to the blind subjects, the effect of the more restrictive conditions of Experiments II and III was relatively slight, compared with the difficulty of the complex and new situation which had confronted them in Experiment I. Consequently, in Experiments II and III the normal subjects did better, in comparison with the blind, than in the other experiments.

Thus far the nature of the cues responsible for the subjects' successes has not been examined. The fact that in the check tests of Experiment III without any obstacle the subjects always kept going, until stopped by the experimenter, and failed to report the presence of any obstacle indicates that in the other tests their judgments depended upon real sensory effects of some kind. The finding that in most cases (and especially in Experiment III) the subjects did better under condition A than under B indicates that in some way the effective cues were deadened by the carpet. This suggests that sound cues may have been involved. Inspection of the data shows that the drop in efficiency from the A to the B condition occurred chiefly in the distance-perception scores, which may mean that these judgments were made on a somewhat different sensory basis than were the close perceptions. This possibility is also suggested by the fact that for P.C. the rank-order coefficient of correlation between the distance-perception and the close-perception scores is −.97, indicating that for her, experimental conditions which favored a good distance perception operated against a good close-perception score. However, for the other subjects the corresponding coefficient values were E.S., −.14, M.S., −.10, and J.D., −.21—all values so close to zero that a virtually chance relationship is indicated between the distance-perception and close-perception processes.

We are put on our guard against an acceptance of the subject's

opinion as a source of evidence by results such as those of the best subject, E S , who despite his initial belief that his obstacle perception depended entirely upon cutaneous pressures localized on his forehead found himself in Experiment IIIB shuffling along on the double carpet, in his own words, "listening for the obstacle"

The preliminary experiments thus served a number of purposes Besides accustoming the blind subjects to the experimental situation and disclosing the ability of the normal subjects to improve through practice, they furnished norms for all the subjects (*i.e* , standards of their ordinary performance) with which the results of further special experiments could be compared Furthermore, these experiments were exploratory in the sense that their outcome guided the planning of procedures and controls to be used in the later investigations

THE MAIN EXPERIMENTS (IV–VII)

Experiment IV. The first of the main experiments was designed to test one principal variant of the "pressure theory," namely, that the avoidance of obstacles by the blind depends upon cutaneous pressure effects aroused by reflected air currents or air waves If the perception of obstacles has such a basis, the subject should be unable to perceive and to avoid obstacles when all ordinarily exposed areas of the skin are covered, even though auditory sensitivity remains unimpaired Experiment IV was designed to test this hypothesis

Apparatus and Procedure The procedure of Experiment III was repeated, except that no area of the subject's skin was left uncovered His head and face were covered with a heavy felt veil which hung loosely down over his chest, shoulders, and back and was prevented from touching his skin at any point by a headboard of insulite from which it was draped, his head was also covered by a felt hat The subject's arms were covered by rolled-down sleeves, thrust into the cuffs of wool-lined leather gauntlets which covered his hands Although in various preliminary tests this arrangement eliminated the tactual effect of air currents set up by an electric fan blowing toward the subject from a distance of 10 ft and by the fanning movements of the experimenter's hand directly in front of the subject's face, the subject was able to hear through the veil with only a slight reduction in intensity Trials under conditions A and B, except for the differences noted, were performed as in Experiment III (see Fig 12)

Results Contrary to what would be expected from the cutaneous pressure hypothesis, the results as summarized in Table 1 show that all four subjects were almost always able to perceive the obstacle both at a distance and close by Although a limited impairment is indicated by the fact that the subjects were not quite so successful as in Experiment III, their performances were sufficiently good to demonstrate that a cutaneous type of stimulation (as by "air waves") is not a *necessary* condition for obstacle avoidance [1] Furthermore, stimulation by air currents (*e g* , through the reflection of one's breath from an obstacle) cannot be a necessary condition for the close per-
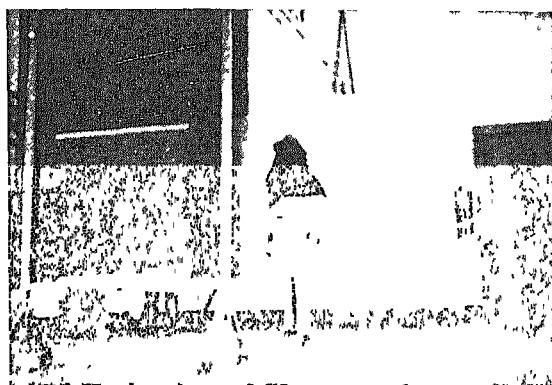
FIG 12 Tests in Obstacle Perception Experiment IV

The subject approaching the obstacle in Experiment IV, condition A Wearing the felt veil and head covering topped by a felt hat, with arm covering and gloves, he approaches the obstacle with every appearance of confidence and perceives it every trial

ception of obstacles, in view of the fact that collisions were avoided at distances which, on the whole, differed but slightly from those of Experiment III

In general, the results of Experiment IV corroborate those previously obtained, especially as concerns the superiority of the blind subjects As suggested above, comparison of the results with those for Experiment III suggests a partial impairment in sensitivity in some instances Thus, although E S was again superior to the others, his performance fell below his standard in Experiment III, as indicated by the act that his distance perceptions were shortened by 50 per cent and his close perceptions lengthened about 25 per cent

[1] A *necessary* condition is a requisite and basic condition in the absence of which the phenomenon (here, obstacle avoidance) cannot occur

on the average, while the number of his collisions increased in series B In contrast, the performance of M S. was better than in Experiment III in all respects save collisions

Discussion Although the results of this experiment indicate that the cutaneous effect of reflected air waves was not a *necessary* condition for perceiving obstacles by the subjects, further tests (see Experiment V) are required to find whether they are a *sufficient* condition[1] On the other hand, the results indicate that echoes of sound waves actually are a *sufficient* condition for the responses to obstacles E S finally admitted his dependence on sound, through discovering that "making a little noise," as by scraping his stockings on the carpet under condition B, was necessary for getting "an impression of the screen" M S reiterated his reliance on sound, and the behavior of both the normal subjects (*e g* , continuous scraping of feet) suggested a similar dependence Certain deficiencies in the scores, particularly in the general performance of E S and in the close perceptions of all subjects, might be attributed either to the loss of cutaneous cues or to a reduction in the effective reception of auditory stimuli through wearing the veil (To determine this special point, further experiments were undertaken) In this experiment, as before, a lack of consistency in the distance and close perceptions of the subjects suggests that the two appraisals of the obstacle depend upon sensory bases which are different at least in part

Experiment V. This experiment was directed toward answering three questions raised in Experiment IV (1) Are reflected sound waves (either sensed tactually or heard) *necessary* conditions for the perception of obstacles? (2) Are object-reflected air or sound waves which tactually affect exposed skin surfaces *sufficient* conditions for the perception of obstacles? (3) Are the object-reflected currents of the subject's breath, effective tactually or through hearing, *sufficient* conditions for the close perception of obstacles? In view of the fact that experimental conditions which would make possible the answer to the first of these questions would also be adequate for answering the

[1] A *sufficient* condition is one which is capable of producing the phenomenon under suitable conditions but is not "necessary" since the phenomenon presumably can occur in its absence Thus the odor of a wooden obstacle or the warmth of a radiator may be sufficient conditions for perceiving those objects without sight, but they are not necessary for such a perception

other two, Experiment V was directed at question 1 It was decided that the complete elimination of audition should answer this question without incurring the technical difficulties of controlling possible cutaneous effects of sound waves Because plugging the ears would also block nonauditory effects (*i e* , tactual stimulation) on the external meatus and the tympanic membrane, the outcome of this experiment could not be completely decisive for the auditory theory, although it would be crucial for the facial-pressure variant of the cutaneous-pressure theory
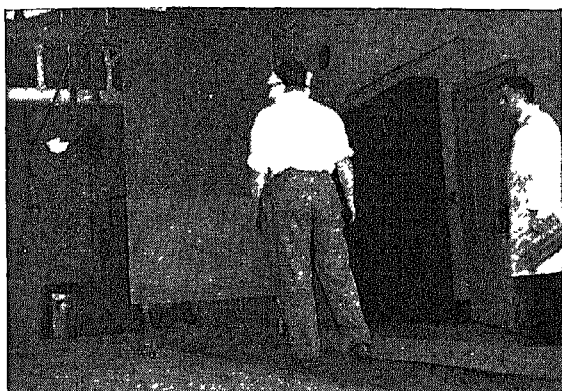
FIG 13 Tests in Obstacle Perception Experiment V

One of the subjects approaching the obstacle screen with ears covered in Experiment V, condition A With his hearing reduced greatly in sensitivity, he walked toward the screen hesitantly and ran into it on every one of 50 trials, as did all of the subjects

Apparatus and Procedure For all tests in this experiment, the subject's ears were completely stopped with special plugs of the type used in mine-safety precautions, topped by beeswax and cotton-wool stoppers in the meatus and concha, a beeswax-cotton shield closely fitting the pinna, and over this two layers of cotton batting held in place by a pair of ear muffs lined with cotton wool The entire device was held in place by the elastic bands of the regular blindfold The subjects thus equipped could not hear the sound of their footsteps or an ordinary conversation Except for the blindfold, the subject's face was uncovered and open to all types of cutaneous stimulation from air currents, reflected breath, and the like The situation under condition A in this experiment is represented in Fig 13

Results None of the subjects were able to perceive the obstacle

under the conditions of this experiment. They all collided with the screen in every one of 100 successive trials, and were as completely lost in the A series as in the B series (see Table I). With contact of the feet on the carpet runner apparently serving as the only source of cues, all the subjects reported that they were "unable to hear," in spite of their walking with head thrust forward as if straining to do so. E. S. now walked with his hands held up "apprehensively" in front of him, and M. S. reported, "I cannot get any cues at all."

The results of this experiment may be taken as demonstrating that air and sound waves reflected to the skin of hands or face were not *sufficient* conditions for the perception of obstacles by these subjects.[1] The conclusion seems justified that "Aural stimulation, felt or heard, is a *necessary* condition for the perception of obstacles by our Ss. Under the conditions of this experiment we cannot determine whether pressure-stimulation from the external ear (meatus and tympanum) or audition is the necessary condition. Though willing to hazard the opinion that our Ss' failure to perceive the obstacle was due to the loss of audition, . . . we have neither the right nor the desire to be dogmatic nor do we wish to transcend our results. A decision concerning this point can be reached only through further experimentation."[2]

A previous tentative conclusion that the distance and close perceptions derive from at least partially different sensory bases is not negated by the results of Experiment V, as might be thought at first consideration. The inability of the subjects to perceive the obstacle either at close range or at a distance indicates only that ear stimulation is a *necessary* condition for both, but does not mean that the distance and close judgments have precisely the same sensory basis. For example, the judgments might rest on auditory cues of different types, or one might depend on audition and the other on nonauditory

[1] One of the subjects, P. C., in some additional tests, was able to perceive the object when very close to it through the reflection of air from forcible breathing through the mouth. However, none of the subjects (including P. C.) could perceive the obstacle, even when very close to it when they breathed normally through the nose.

[2] "Experiments with deaf Ss having inner ear defects, who could serve without stopping their ears—thus leaving the meatuses and tympanums open to pressure stimulation—would be crucial." Such experiments were carried out in the second investigation, to be described.

pressure effects on meatus and tympanum Such possibilities remained to be explored

Experiment VI. In this experiment the investigators set out to test a possible objection to their conclusion from Experiment V, that reflected air and sound waves are not sufficient conditions for the perception of obstacles by the subjects The question might be raised whether the failure of the deafened subjects to detect the screen was due to some deleterious effect of the loss of hearing on cutaneous perception Although this might be considered a somewhat remote possibility, further experiments seemed desirable to investigate it Experiment VI was therefore aimed at testing whether pressure stimulation of exposed skin might be a *sufficient* condition for obstacle perception when hearing is functionally intact although auditory stimuli are useless as cues

Apparatus and Procedure To eliminate usable auditory stimuli, a "sound screen" was used, a constant, continuous sounding tone of 1,000 cycles per second at moderate intensity, produced by an electrically driven tuning fork This stimulus was delivered to both ears of the subject by earphones throughout each test, with the result that auditory cues from the obstacle were rendered useless although hearing was not functionally impaired Any hypothetical interference with possible cutaneous facial cues through a complete blocking of audition thereby was ruled out A failure to localize obstacles under these conditions could be due only to the elimination of necessary auditory cues

Results Without auditory cues, the subjects could not perceive the obstacle at any distance, but collided with the screen on every trial as in Experiment V Because failure was complete under condition A, the even more difficult test of condition B was not run The subjects behaved as in the preceding experiment, walking slowly and noisily, the blind subjects with hands held up before them, all subjects as if listening closely

The experimenters conclude that the complete failure of obstacle-perception in Experiment V was not due to any secondary impairment of cutaneous perception through loss of hearing, but to the absence of indispensable auditory cues In Experiment V such cues were eliminated through the deafening effect of the ear coverings, in Ex-

periment VI through the masking effect of the sound screen The previous conclusion thereby is strengthened, that auditory stimulation is a *necessary* condition and that air currents or sound waves which affect the skin are not *sufficient* conditions for obstacle perception

Experiment VII. *Apparatus and Procedure* In Experiment IV, a special felt covering of face, head, and hands eliminated the possibility that cutaneous-pressure stimuli (through air waves) might be responsible for obstacle avoidance In Experiment VII the sound variant of the pressure theory was tested by eliminating sound waves that might stimulate exposed areas of skin and serve as cues, while permitting sound waves from the footfalls to reach the subject's ears The critical experimental condition was obtained by placing the subject in a soundproof room and having him judge the experimenter's approach to an obstacle by means of the electrically transmitted sounds of the experimenter's walking In his approach to the obstacle (the end wall of the hall) the experimenter held at shoulder height a microphone pickup through which the sounds of his leather shoes on the hardwood floor were transmitted by wire through a power amplifier to the high-fidelity headphones worn by the subject In the successive trials under condition A, the experimenter walked toward the end wall from starting points ranging from 6 to 30 ft , as the subject himself had done in Experiment I

The communication system was so arranged that the subject and experimenter could talk back and forth between trials, the experimenter could give "Ready!" signals, and the subject could make his reports directly to the experimenter The experimenter walked at a moderately slow rate until the subject requested him to go even more slowly, as he did at points of critical judgment After the subject had said, "There!" to indicate his distance perception of the wall, the experimenter stopped and recorded the distance He then continued without a signal (to eliminate unwanted cues) until he had bumped the microphone against the end wall or until the subject had signaled a "close perception" of the wall by saying, "Stop!"—whereupon a second measurement was made The situation of subject and experimenter in this experiment is shown in Fig 14

Results As the summary of results in the table shows, the subjects made their distance and close perceptions about as effectively as in

the control experiment (Experiment III) and did not "collide with the wall" very much more frequently than in that experiment It is probable that the number of collisions would have been even smaller had the subjects been able to control the rate of the experimenter's

FIG 14 Tests in Obstacle Perception Experiment VII

14*a* The experimenter in Experiment VII approaching the obstacle wall with pickup microphone in his right hand at shoulder height

14*b* The subject, seated in a soundproof room, listens through high-fidelity earphones to the experimenter's footsteps, and speaks his "distance perception" and "close perception" over the phone system to the experimenter

advance as precisely as they could control their own progress in Experiment III All subjects stated that the sounds of the experimenter's footsteps approaching the wall were different from the sound of their own steps as in Experiment IIIA

In comparison with the results of Experiment III, the performance of E S was considerably poorer, whereas that of the other three subjects was only slightly different The greatest loss for E S was in his close perception of the obstacle, which was 2 74 ± 0 34 ft as against 0 50 ± 0 000 ft in Experiment IIIA On the other hand, the smaller sizes of his M V 's in Experiment VII (10 9 per cent as against 40 7 per cent in Experiment IIIA) suggest that the cues which served as the basis of his distance perceptions in Experiment VII were more constant in their effect, although weaker than in Experiment IIIA

Discussion The fact that the subjects were able to perceive the wall when auditory cues alone were available constitutes evidence that (1) sound-wave stimuli are a *sufficient* condition for obstacle perception in this situation, (2) cutaneous stimulation of exposed areas of skin is not a *necessary* condition for such perception, (3) both variants of the pressure theory are untenable, so far as they apply to exposed areas of skin, and (4) currents of air reflected to the subject from his breathing are not *necessary* conditions for the close perception of the obstacle

Although these results confirm the conclusion of Experiment V that both the distance and close perceptions depend essentially upon auditory cues, they are not decisive with regard to the tentative conclusion from Experiments I to IV that these two judgments rest upon different sensory bases The experimenters suggest that stimulation of the ears may involve pressure effects as well as audition, and that these effects might have different functions in the distance and the close perceptions It is true that the subjects said that the principal basis of their judgments was audition, and that none of them at any time mentioned pressure, however, in such matters it is justifiable to regard the subject's comments as suggestive only and not as a necessarily valid item of evidence concerning what the cues actually were

It is worth mentioning in this connection that in Experiment VII absence of the very high sound frequencies (*i e* , those above 12,000 cycles per second, which were not transmitted by the apparatus) was noticed and reported by the subjects This fact suggests that the poorer performance of the subjects in Experiment VII (as compared with Experiment III) may have been due to the possibility that such high sound frequencies play a role of some importance in the perception of obstacles As will be seen later, the results of the third investigation justified this interpretation

GENERAL DISCUSSION OF THE FIRST INVESTIGATION

The results of this first series of experiments indicate that experienced blind individuals avoid obstacles in their path and thus guide their progress by responding to a pattern of reflected sound which may possibly be supplemented by ear-pressure effects The complexity of the process is revealed by the fact that although the general nature of the cues was clear, the two blind subjects apparently utilized such cues in different ways Thus M S ordinarily clicked his heels as he walked and asserted that he used auditory cues, whereas E S typically did not seem to need extra sound, and at first insisted that facial cutaneous cues were the basis of his judgments However, the experiments yielded results which demonstrated that such cutaneous cues were not adequate guides for any of the subjects, and that all four subjects including E S needed auditory stimuli in order to avoid obstacles

The initial ineptness of the sighted subjects in avoiding obstacles when blindfolded indicates that they, like most people, had never really begun the special process of perceptual learning which experienced blind individuals evidently master If the sighted subjects had been individuals such as experienced woodsmen or night watchmen, who often have occasion to practice making their way about in the dark, different results might well have been expected It would be interesting to know whether steamship pilots who frequently need to direct the immediate course of their vessels without visual cues, as in the fogs of Puget Sound, use the reflected sound patterns of their frequently used whistles much as blind persons depend upon sounds reflected from their footsteps

SECOND INVESTIGATION TESTS WITH BLIND-DEAF SUBJECTS[1]

PURPOSE AND GENERAL PLAN

Although the results of the first investigation demonstrated that the subjects were using sensory cues, and that these very probably were auditory stimuli, the latter point was not established beyond all question since the role of cutaneous cues affecting exposed surfaces of the outer ear was not altogether controlled in any of the experiments The experiments of the second investigation, however, provided the basis for a crucial test of this question

[1] Adapted from Worchel, P, and K M Dallenbach "Facial Vision" Perception of Obstacles by the Deaf-blind *American Journal of Psychology*, 1947, vol 60, pp 502-553

For this test the experimenters decided to use subjects who were both blind and deaf but whose outer ears were intact and had normal cutaneous sensitivity. If blind persons without hearing should possess a good obstacle-avoidance capacity, this fact would indicate that the ear-cutaneous factor is a sufficient condition for the ability, and further investigations to establish the role of hearing would be essential.

Subjects. Ten blind-deaf persons were found (eight men and two women, ranging in age from thirty-four to fifty-five years) who possessed the qualifications judged essential for this investigation: although deaf, all had intact outer ear parts, and all were fairly active individuals who got about with some confidence, although clumsily. Thus they were likely to have learned to utilize all available sensory capacities to the full in their orientation. Their vision and hearing were examined by specialists. Most of them were found to be completely deaf and blind, and the others were judged sufficiently close to zero sensitivity in these sensory fields to serve as subjects. None had outer ear defects that might have affected cutaneous sensitivity in that region.

TESTS AND RESULTS

Tested under condition IA, the one most favorable to obstacle avoidance, these subjects made very poor scores in detecting the end wall, in complete contrast to the excellent scores made under this condition by the two blind-hearing subjects in the first investigation. Eight subjects collided with the wall in more than 33 per cent of the trials, four collided with it in more than 50 per cent. All subjects frequently collided with the wall before having made even a distance-perception report. With further trials, a few of them showed a limited improvement, but in all cases their scores were far inferior to those of the hearing-blind subjects in the first investigation.

Circumstances suggested that the limited success of some of these subjects was due to the use of special cues for judging distance, *e.g.*, to the use of floor irregularities to estimate the position of the starting point by means of foot contact. To test this hypothesis, the screen was used as the obstacle, and was placed in different positions on successive trials as in Experiment III. All of the subjects were poorer than before in every respect. When 25 "catch" trials *without the screen* were introduced at random, all except one of these subjects

These results indicate that in the absence of hearing there is no possibility of an obstacle perception at all comparable to that of hearing-blind subjects

The only two deaf-blind subjects who had any success in obstacle avoidance, F B and M St, had a slight degree of hearing, and both wore hearing aids In further tests with M St involving random placements of the screen in the hall, it was ascertained that her first limited success was really due to the habit of walking about 10 ft before reporting a distance perception, and 10 ft more before reporting a close perception, *i e*, with her it was a matter of guessing The results showed that she was not really helped by the hearing aid, except that it set her at ease and increased her confidence in moving about

The really puzzling case was F B, who had had some success throughout the tests up to the final one, described below He objected to the pressures of the special light-tight blindfolds worn by the other subjects and would not permit his eyes to be taped or otherwise closely covered, complaining that unless his blindfold was loose there were distracting tensions and pressures which impaired his "facial-pressure sense" When tests were made in complete darkness he progressed very haltingly and collided with the wall on every trial, then objected to continuing, on the ground that darkness affected his nerves At length a test was found to which not even F B objected Trials were made in which F B approached the screen from varying distances and places wearing a special close-fitting cardboard blindfold which was open to light from above, but which was shielded otherwise so that no light would reach the eyes (even by reflection) from the obstacle Wearing this device, F B had no more success in perceiving the obstacle at any distance than had any of the other blind-deaf subjects He at last admitted that what he had always thought was "facial vision" must really be a very limited sensitivity to light

THIRD INVESTIGATION NATURE OF THE AUDITORY CUES IN OBSTACLE-AVOIDANCE BY THE BLIND[1]

Problem After the second investigation had furnished conclusive evidence that auditory cues are responsible for the skillful avoidance of obstacles by blind individuals, a further study was conducted to

[1] Adapted from Cotzin, M and K M Dallenbach, "Facial Vision" The Role of Pitch and Loudness in the Perception of Obstacles by the Blind *American Journal of Psychology*, 1950, vol 63, pp 484-515

determine what characteristic of auditory stimuli may be critical for this ability

Subjects. Two blind and two sighted subjects served in these experiments One of the sighted subjects was P C , who had participated in the first investigation

Situation and general procedure. The arrangement of the experimental situation resembled that in Experiment VII of the first investigation The subject, seated in a completely dark and soundproof room was asked to judge the spatial relation to the obstacle of an experimentally produced noise reflected from the masonite obstacle screen in the distant experimental hall, and transmitted to him electrically His judgment was expressed specifically by his accuracy in moving the sound-source as close as possible to the obstacle, without collisions

In different experiments, both noises and pure tones were used as critical stimuli The noise, a complex pattern of several frequencies all of equal loudness, was produced by means of a push-pull amplifier and amplified by the loud-speaker The pure tones were produced by means of an RCS beat-frequency oscillator, the frequency range of which was 30 to 15,000 cycles per second The sound used as stimulus was transmitted to the subject's earphones through a circuit leading from a microphone mounted below the loud-speaker at "ear height" Both loud-speaker and microphone were attached to a carriage which moved smoothly and noiselessly along a wire track through the center of the experimental hall from one end to the other The rate of movement of this carriage toward the obstacle was controlled by the subject through the use of a foot pedal

Thus the subject made his close perceptions of the obstacle by "remote control," endeavoring to avoid "collisions" much as in Experiment VII, in which he controlled the experimenter's progress verbally In the various trials of successive experiments with the noise and with several pure tones, four starting distances of 6, 12, 18, and 24 ft between sound and obstacle were used in a haphazard order With the noise as stimulus, the judgments under these conditions were almost as good as in Experiments I and II of the first investigation, in which the subject himself moved toward the obstacle On this basis it was concluded that the apparatus and procedure were suitable for critical tests Preliminary series of trials were carried out, as in the

first investigation, in which the inexperienced sighted subjects acquired the ability to perceive the obstacle with some accuracy under the conditions described above, and the blind subjects were demonstrated to have a high degree of skill in such obstacle-location

Results. In the principal experiments of this investigation it was first desirable to determine whether the subject's judgments were dependent upon changes in intensity (*i e* , loudness) of the noise as the source approached the obstacle or receded from it For this purpose, the threshold intensity (*i e* , the least intensity of sound necessary for hearing the noise) was determined at distances of 1 to 6 ft from the obstacle It was found that the intensity thresholds were the same for all these distances This result indicated that perception of the obstacle under these conditions could not depend upon *intensity* differences of sounds reflected from it, for if intensity differences were critical, the intensity thresholds would have differed according to the distance of the sound-source from the screen

To determine whether the obstacle-localization depended upon *frequency*, *i e* , pitch differences in the sound as the source was moved toward or away from the obstacle, pure-tone stimuli of particular frequencies were substituted for the noise [1] On each trial, one particular tone of controlled pitch was used as the critical stimulus By appropriate means, the different tones used for any subject on the successive trials of a series were held at constant loudness The following frequencies were used 128, 256, 500, 1,000, 2,000, 4,000, 8,000, and 10,000 cycles per second Higher frequencies were not tested, since the apparatus—oscillator, loud-speaker, transmission, etc —could not produce and transmit sounds higher than 12,000 cycles per second with fidelity

The outcome was clear all of the subjects, blind and seeing alike, were able to detect the obstacle at close range (typically at a distance of 1 ft or less) when the tone of 10,000 cycles was used, but made poor and variable scores with the lower tones With the 10,000 cycle tone as stimulus, both of the two blind subjects stopped the carriage very close to the obstacle in 40 out of 40 trials, and the two sighted subjects were successful in 39 and 37 trials, respectively, out of 40 With

[1] Oscillographic records of these tones, taken by a connection from the subject's earphones, showed that they were all "pure," *i e* , produced by sound waves of a single frequency

tones of 8,000 cycles and lower, collisions predominated in most of the series, and in most of the relatively few successful trials the distance of close perceptions were considerably greater than with the 10,000 cycle tone

The experimenter concluded that the most skillful avoidance of obstacles by the blind occurs when there is a reflection from them of very high tonal frequencies Although an explanation of the superiority of the high-frequency auditory cue must await further investigations, it is considered likely that differences in the reflection and absorption of high and low frequencies by obstacles such as the masonite screen may be responsible for the results obtained

General Discussion and Conclusions

These three investigations demonstrate very clearly that a solution to problems of this kind can be obtained only by means of precisely controlled experimental methods The experimenters concluded that "auditory stimulation is both a *necessary* and a *sufficient* condition for the perception of obstacles by the blind," and that the cutaneous surfaces of the external ears are not sufficient for the perception of obstacles The fact that active blind-deaf subjects, who lacked hearing but possessed intact outer ears with normal cutaneous sensitivity, could not avoid obstacles with any degree of adequacy but behaved much as had the blind-hearing subjects in Experiments V and VI when hearing was eliminated, demonstrates that the cutaneous factor is not a sufficient condition for obstacle perception These results therefore point clearly to sound as the critical and necessary stimulus for the skilled avoidance of obstacles by the blind

The results of the first investigation show that the blind efficiently make their way about through having developed a heightened perceptual responsiveness to sensory cues which are relatively ineffective in the orientation of most sighted individuals That such performances actually represent complex learned acts of skill is indicated clearly by the manner in which both of the sighted subjects improved during the experiments in the first investigation At first completely without competence in avoiding obstacles when blindfolded, both of them improved rapidly and soon acquired a considerable degree of skill in obstacle-avoidance without the use of vision This skill was exhibited not only in perceiving the experimental obstacles from a

distance but also in avoiding collisions when close by, although neither of the sighted subjects ever became as proficient as the blind subjects. It is quite probable that the superiority of the blind subjects over blindfolded sighted subjects would have been much greater if further tests had been made under the complex conditions of orientation in everyday situations, as for example in crossing streets and avoiding moving objects out of doors.

One rather impressive feature of the results was the manner in which they flatly contradicted the strong convictions of subjects, such as the blind E.S. and the deaf-blind F.B. in the first and second investigations, respectively, that their capacities depended upon some sort of "sixth sense" such as the term "facial vision" would suggest. Actually, the skilled object-avoidance of E.S. turned out to depend upon auditory cues, and the inferior performance of F.B. upon limited visual cues. A frequent practice in attempting to explain the many extraordinary phenomena of orientation in space is to postulate a "sixth sense" or a special "unknown direction sense" without having adequately investigated the functions of known senses. The elimination of "facial vision" as a new "sense," to account for the orientation of blind individuals, when that esoteric concept was tested in the investigations reported in this chapter, should suggest a measure of caution to those who prefer to answer difficult questions about human behavior by leaping at once to an occult type of explanation.

It should be mentioned in this connection that the term "sense" has been used in vague and misleading ways in discussions of orientation. "Unknown sense," as the expression is sometimes used in regard to orientation, should be interpreted to mean only the inadequately investigated sensory basis of an impressive known ability. Consideration of skilled obstacle avoidance in the spatial orientation of the blind supports this conclusion. The phenomenon is a striking and even spectacular one, and its basis has been obscure and subject to much speculation in the literature. However, when the problem was attacked by controlled experimental methods, it was shown that the sensory cues on which this orientation depends are furnished by a known type of sensitivity, namely audition, and that the hypothesis of a "sixth sense" is entirely unwarranted.

In addition to studies of spatial orientation in man, there have been numerous investigations of this ability in lower animals. As an

example of the latter, an investigation of obstacle-avoidance in bats is reported below

THE SENSORY BASIS OF OBSTACLE AVOIDANCE BY BATS

INTRODUCTION

The skill with which blind people avoid obstacles has its parallel in the amazing ability of many species of bats to fly at night through forest foliage or to negotiate the tortuous turnings of dark caves where it would seem that nonvisual cues of some kind must be depended upon Although the problem has been the object of investigation since 1794 and numerous types of explanations have been offered, it is only in recent years and particularly in the experiments of Griffin and Galambos[1] that the question has received a convincing answer Considered in relation to the foregoing experiments with human subjects, a brief summary of the principal results on bat orientation should serve to demonstrate even more convincingly that no mysterious kind of sensitivity need be postulated to explain these performances

In bat orientation, as in the problem concerning the human blind, both auditory and cutaneous cues (*e g* , air currents on wing membranes or snout) have been hypothecated. One investigator found that bats strike obstacles when their ears are plugged, but not when other changes are made, such as blindfolding them or covering their wings However, he had observed that a flying bat seldom makes any sound audible to man and was led by his observations to postulate that the basis of orientation was pressure effects upon cutaneous receptors in the ear Eighteen years after the English physiologist Hartridge had suggested that bats in flight may emit extremely high-pitched sounds which, reflected from objects in their path, could serve as orienting and object-avoidance cues, Pierce and Griffin in 1938 demonstrated that bats actually make such notes during flight, as clicks or pulses of sound which appear in successive short bursts With adequate recording devices, tones of frequencies from 30,000 to 70,000 cycles per second were picked up from flying bats These very high frequencies are called "ultrasonic," since they lie considerably above the upper human threshold which is as high as 20,000 cycles per second for

[1] Griffin, D R , and R Galambos The Sensory Basis of Obstacle Avoidance by Flying Bats *Journal of Experimental Zoology*, 1941, vol 86, pp 481 506

many individuals but much lower for others[1] It remained to demonstrate that ultrasonic tones actually serve as orienting cues for the bats that make them.

The Experiment of Griffin and Galambos[2]

Method. Bats were made to fly through a barrier of parallel wires strung vertically from floor to ceiling so that the space between adjacent wires was 12 in (a distance about 3 in greater than the maximal flight wingspread of the bat species to be tested) As the subject flew back and forth through the barrier, a count was kept of the misses and hits of wires (the latter being indicated by a clearly audible sound when wing brushed wire) Thus a low percentage of hits meant high skill in object-avoidance

A minimum of 50 trials was run with each of 144 normal bats, and with several subjects tested with eyes, ears, or mouth covered (*i e*, "blind," "deaf," and "gagged" subjects) before they were later tested in a normal condition

Results. Although the bats were somewhat groggy at the time because of an incomplete recovery from hibernation, the average for 144 *normal subjects* was 35 per cent hits (*i e*, contacts with wires) Twenty-eight of these subjects scored fewer than 25 per cent hits, and only seventeen of them had more than 50 per cent hits All of the normal subjects were considerably better in their scores than the 65 per cent level of hits which had been calculated mathematically in advance of the experiments as a *chance score* On these calculations, a score of 65 per cent would be made by bats flying through the interwire spaces used in these experiments without any means whatever of detecting the wires Moreover, slow-motion cinema records showed that in approaching the wires a bat would often modify its flight appropriately, as by folding its wings somewhat or by banking with vertically spread wings, thereby avoiding a collision

Blinded subjects (eyes covered with a dark blue collodion preparation, noninjurious and removable after the test) were as efficient as normal seeing subjects in avoiding the wires When 28 bats of the same spe-

[1] Because the term "supersonic" is used increasingly to refer to speeds beyond the speed of sound, for the sake of clarity it is desirable to refer to "sound frequencies" above the audible human threshold as "ultrasonic" frequencies

[2] Adapted from Griffin and Galambos *op cit*

cies were tested under this condition, they scored 24 per cent hits, when tested as normal subjects, they scored 30 per cent hits The difference was attributed to chance, and some nonvisual means of avoiding wires was indicated In fact, most of the bats avoided wires more efficiently with eyes covered than when normal

When 26 bats were *deafened* temporarily by stoppage of the meatus in each ear, their flight became abnormal, and obstacle-avoidance was drastically impaired. A group of 12 subjects averaged 34 per cent hits as normal fliers, but made 65 per cent hits when deafened Another group of 17 subjects averaged 29 per cent hits when temporarily blinded, but their average was 67 per cent hits when both blinded and deafened It will be noticed that these results for deafened bats were no better than the calculated chance score mentioned above. Clearly, the absence of hearing virtually destroyed the capacity for accurate orientation in flight. Deafened bats took to flight very slowly, then flew erratically, and when flying in an open room almost always came into head-on collisions with the walls. [The reader will be reminded of the similarity between this result and the finding with deafened (and blinded) human subjects] It is clear from these results that the efficient avoidance of obstacles by bats depends in some manner upon auditory cues

Hartridge had suggested that the effective sensory basis of orientation might be the ultrasonic utterances of the bats themselves when in flight Such "cries" later were recorded from bats, in extremely short bursts lasting only about 0 002 sec, with 5 to 10 bursts per second from bats at rest, 20 to 30 per second from bats in flight, and 50 to 60 per second from bats approaching obstacles [1] To stop such possible cues at the source (*i e*, to prevent the sound waves from issuing, being reflected from objects, and heard) the snout of each subject in a group of six bats was firmly closed with a loop of thread and a collodion seal, with nostrils open but lips tightly shut This treatment raised the number of hits from 38 per cent to the chance score of 65 per cent on the average "Gagged bats flew in the same clumsy hesitant and bewildered manner as deaf bats" From such subjects no ultrasonic utterances were detectable instrumentally, however,

[1] Griffin, D, and R Galambos Obstacle Avoidance by Flying Bats the Cries of Bats *Journal of Experimental Zoology*, 1942, vol 89, pp 475–490

Also see Griffin, D R Supersonic Cries of Bats *Nature*, 1946, vol 158, pp 46–48

when a small opening was scratched in the collodion as a mouth hole ultrasonic tones were picked up by appropriate recording apparatus and the bats thus treated became able to dodge wires quite efficiently.

Discussion. From the above results the authors conclude that

> All this evidence points conclusively towards Hartridge's auditory theory in a slightly modified form which may be stated as follows Flying bats detect obstacles in their path by (1) emitting supersonic (*i e*, ultrasonic) notes, (2) hearing these sound waves when reflected back to them by the obstacles, and (3) detecting the position of the obstacle by localizing the source of this reflected sound This localization is presumably accomplished binaurally by some auditory mechanism, similar in principal to that used by other mammals for sounds of ordinary frequencies

The term "echolocation" has been advanced by Griffin to denote the use of reflected sounds in nonvisual orientation Although the sounds which are useful to bats in echolocation are considerably above the effective human range, it is clear that the abilities, as demonstrated in the foregoing experiments, have an auditory basis in both human subjects and bats As we know from the third investigation with human subjects, the skilled avoidance of obstacles by the human blind depends upon sounds in the upper ranges of human sensitivity

Despite the similarity of sensory-and-response mechanisms, it appears safe to say that man's capacities for the acquisition of a wide variety of cues and for utilizing them in varied ways in space perception characteristically exceed those of lower animals—not because of a superior sensory acuity, but because of his resources for learning new cues and perceptual relationships The human blind use many obvious auditory cues such as the clicking of heels, tapping of canes, and listening for variations in traffic noises, and also various "minimal cues" that although important are difficult to identify There is little question that experienced individuals typically shift adroitly in the basis of their orientation, according to which auditory cues are most available and most useful under given conditions The further investigation of such matters represents a part of the general study of perceiving in which much work remains to be done

CHAPTER X

THE FUNCTION OF THE BRAIN IN RELATION TO INTELLIGENCE

Introduction

It has been said that the problem of learning is the most important single problem in psychology. In a certain sense, Aristotle prophetically recognized this fact when he formulated his "laws of learning." For many centuries thereafter, the problem remained in the hands of philosophers and received no more than speculative attention until Ebbinghaus began his original and epochal experiments, shortly after 1880. Since that time, an important experimental literature has been developed from the investigation of conditions which are essential for efficient learning and retention. Later, the rapid development of animal psychology and child psychology as experimental subjects greatly broadened the study, particularly with respect to the theoretical understanding of learning.

That learning in a higher animal depends upon the setting up of changes in nervous tissue, and in particular upon changes in the brain, was widely assumed long before the experimental investigation of learning was undertaken. As a result, beginning even before 1810, an extensive knowledge of the structural and physiological characteristics of the human brain has been developed in neuroanatomy and related sciences. Although it was actually a general realization of the importance of the brain in behavior which led to these investigations, knowledge derived from them has not proved of much direct assistance in throwing light on the manner in which the nervous system functions in learning and in retention. There have been no direct experimental studies of the neural changes which are brought about when learning takes place, although studies of reflex action and of the nerve impulse have excited great interest in the question. At present, psychologists have virtually abandoned "synaptic resistance," "drainage," and related hypotheses of a vague nature

concerning the neural changes underlying learning, and new "leads" into the problem are developing from physiological studies on the brain as well as lower nervous centers [1] However, it cannot be said that a clear solution of the problem is discernible at the present time

One helpful sign is the amount of knowledge which has been obtained as to the general function of the brain in behavior Shortly before 1840, *extirpative experiments* (*i e*, experiments involving tissue destruction as the basic method) had been performed by Flourens and other physiologists on dogs and various other lower animals Since that time there has been a series of investigations upon the sensitivity and the "mental capacities" of individuals with nervous injuries resulting either from experimental extirpation (as in lower animals) or from accident or disease (as in man) However, such investigations have yielded little useful evidence for the understanding of neural function in learning Among the reasons for this deficiency have been the use of faulty operative techniques, inaccuracy in reporting both the amount and the location of brain tissue destroyed in a given operation, and the absence of adequate studies of the subject's abilities before and after the operation When experimentation is handicapped by such deficiencies, it is impossible to determine precisely the effect of brain-tissue injuries upon behavioral capacities

However, an important contribution of these early experiments was to show the presence in the mammalian brain of certain cortical *projection areas* The normal function of certain of these areas has been inferred from the fact that injury to them results in deficiencies in specific fields of sensitivity (*e g*, visual, auditory) or in motor deficiencies (*e g*, paralysis) Although the extreme doctrine of the phrenologists, that the brain is divided into many areas which control corresponding psychological "faculties" (*e g*, memory, morality, ambition, etc), lost its scientific standing long before 1900, the existence of the projection areas has influenced many students to think of brain functions primarily as "localized" However, the doctrine of a cortical *association function* also arose as a consequence of the early brain investigations That is, it seemed likely that different areas of the brain might work together in the same learning processes by virtue of their tissue interconnections In their writings, most psy-

[1] Hebb has postulated a modified synaptic-resistance process as the basic neurophysiological event in learning —Hebb, D O *The Organization of Behavior* New York, John Wiley & Sons, Inc , 1949

chologists commonly treat this function rather vaguely, at least as regards the manner in which the brain performs it To clarify such questions the need for a more direct attack upon the problem of brain function is very evident

SYSTEMATIC EXPERIMENTAL STUDY OF BRAIN FUNCTION IN LEARNING

Shortly after 1900, a few psychologists began to experiment upon the problem of brain function They were led into the work mainly by a growing interest in the nature and basis of the learning process Chief among the early experimenters was Franz,[1] who in 1916 first interested Lashley in the question Since then, Lashley has followed an organized program of research upon the problem and has succeeded in attracting a large number of research students to its investigation

Lashley has investigated two problems in particular First, the manner in which brain functions permit the learning and retention of particular habits, and second, which characteristics of the brain determine "intelligence," *i e*, the relative capacity of an animal for modifying its present behavior or for acquiring new behavior He has consistently used the animal's learning ability as an indicator of its intelligence, studying in particular the effect upon learning ability of experimentally altering the brain tissue possessed by the animal The present chapter constitutes a review of some of Lashley's principal findings [2]

First of all, we should consider the principal variables which must be kept under control by any scientist investigating how the brain functions in the learning process, if he is to be successful in his experimentation

1 It is important to know the *sensory control and the movements which are essential* to the particular habit to be learned As for sensory control, this varies according to the nature of the problem which the animal must learn and also according to the setting in which this problem is presented Under certain conditions, the mas-

[1] For a general summary of the problem see Marquis, Donald G The Neurology of Learning, in Moss, F A, ed, *et al Comparative Psychology*, Chap 7 pp 153–177 New York, Prentice Hall, rev ed, 1942

[2] Adapted from Lashley, K S, *Brain Mechanisms and Intelligence* Chicago, University of Chicago Press, 1929, and from more recent papers For a summary and discussion of Lashley's work see Maier, N R F, and T C Schneirla, *Principles of Animal Psychology*, Chap XIV New York McGraw-Hill, 1935

tery of a habit may involve only one field of sensitivity (*e g* , vision alone), in which case we may speak of the habit as a "specific" one In this sense, Lashley used the light-dark discrimination habit as a specific habit. Obviously, a blind animal would not be able to learn this habit, just as a deaf animal would be unable to learn a habit which specifically depended upon auditory control On the other hand, when the mastery of a habit requires the availability of stimuli in two or more fields of sensitivity, we may speak of a "general" habit For example, the learning and the performance of an elevated-maze habit have been found to require visual, olfactory, auditory, and perhaps other types of sensitivity as well Maze habits, characteristically, are of the general type In the same sense, a habit may be specific or general with respect to action *specific* if one particular movement or series of movements alone will serve, and *general* if no one movement or movement series is indispensable for its performance In this chapter we shall be concerned mainly with the importance of brain function for *sensory control* in learning, attempting to determine whether there is a difference in brain function according to whether the animal learns a specific or a general sensory habit

2 *The relative difficulty of the problem* which is used to test the animal's intelligence must be known and controlled, or the results will have little significance for the study of brain function In the studies to be reported, Lashley used the light-dark discrimination as a *simple* "specific habit," and the brightness discrimination as a *complex* (*i e*, more difficult) "specific habit " In testing the formation of "general habits," he used three maze patterns of increasing difficulty *Difficulty of problem* was thus graded for both the specific and the general habits

3 Another way in which to discover the importance of cerebral function for learning is to change in controlled ways *the amount of cortical tissue* possessed by the subject Lashley studied this factor by operatively reducing for different groups of rats the percentage of intact cortex Since he tentatively had adopted performance in learning given habits as a measure of "intelligence" by comparing the learning records of normal animals with that of various groups of cortically operated animals, Lashley hoped to find whether the intelligence of an animal would be reduced in accordance with the amount of cortex which remained.

APPARATUS

1. Specific (Visual) Habits. For the tests of simple and of complex specific habits a light-discrimination box was used (Fig 15*a*) The rat was released into an enclosure, at the farther end of which he came directly toward the edge of a partition which separated two compartments In the light-dark problem, which tested a *simple specific habit*, either compartment was lighted for a given trial while the other compartment was darkened In the brightness-discrimination, which tested a *complex specific habit*, a light of different intensity was pre-
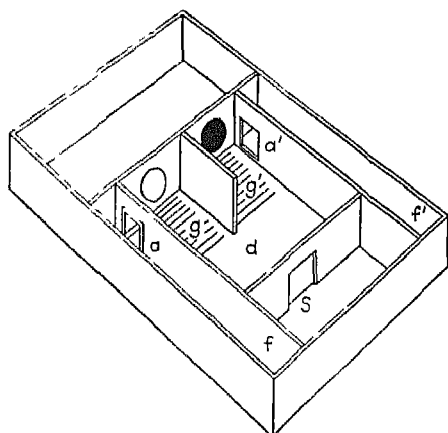
FIG. 15*a* Apparatus Used for the Testing of Visual Discrimination Habits

The rat starts from S, at *d* responds to the stimuli, and receives a shock at *g* (or at *g'*) if he turns to the 'incorrect' stimulus If the response is "correct," the animal is free to pass through door *a* (or *a'*), reaching *f* (or *f'*) where he receives food (*Redrawn from Lashley*)

sented through a round window at the end of each compartment Side doors permitted the animal to escape from the apparatus after passing through either of the two compartments The floor of both compartments was wired so that a shock could be given the animal when an incorrect response was made (In later studies the "jumping apparatus," shown in Fig 15*b*, has been used and has proved much more satisfactory than the discrimination box for the purposes of this experiment)

2. General (Maze) Habits. In testing the learning of general habits alley mazes of three degrees of complexity were used (Fig

16) Maze I, the simplest of these problems, had a short true pathway with but one blind alley between starting point and food-box, Maze II, which was more complex, had a somewhat different true pathway with three blind alleys, and Maze III, which was the most complex of these mazes, had eight blind alleys, some of which turned off to right and some to left from the true pathway

PROCEDURE

Procedures Common to All Tests. *Original Learning Tests* In the five problems which were used (*i e* , the simple and complex visual problems, and the three maze problems of different complexity), hunger was the drive employed and food was the reward for each successful trial First, each of the problems was given as a learning test, both to normal rats and to rats operatively deprived of part of their cerebral cortex The training of the operated animals was started two weeks after they had been subjected to the brain operation The normal and the operated animals were compared as to their efficiency in learning, on the basis of the total number of errors they committed in learning a particular problem, and also in terms of their trial-to-trial error scores

FIG 15*b* "Jumping Apparatus" Used by Lashley to Test Visual Discrimination Habits

The rat jumps from the stand *S* against card *l* or *r* The "correct" card is loosely held in place so that it falls readily when the rat jumps against it, letting him pass through the opening to the food place (*f p*) The "incorrect" card is fastened securely so that the rat falls from it into the net (*n*) (*Redrawn from Lashley*)

Retention Tests Each of the five problems was also presented as a retention test (*i e* , a test of memory) to normal animals as well as to animals which had been subjected to a cortical operation *after* they had learned the problem when in the normal condition The purpose of this test was to discover how many trials were required and how

many errors were committed by animals of the two groups in relearning each problem [1]

The Cortical Operation The animals were operated upon under ether anesthesia A hole was drilled in the exposed skull, and predetermined portions of cortex were destroyed in each of the two hemispheres with an electrocautery In the operation, from 1 to 50 per cent of the total amount of cerebral cortex was destroyed All operations were bilateral (*i e* , in each case, both cerebral hemispheres were involved) In was arranged to have one or more groups of animals in which each of the principal areas of the cortex had been destroyed
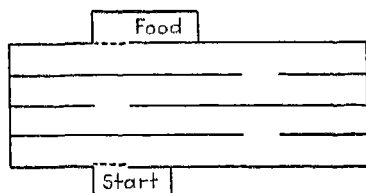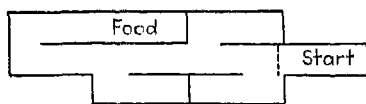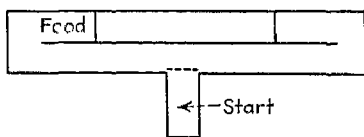
FIG. 16 Maze Patterns of Graded Difficulty Used by Lashley in Testing General Habits (*Redrawn from Lashley*)

Two weeks after the operation, training was begun, provided that the animal had fully recovered After the learning and retention tests had been completed, the animal was killed and a histological study (*i e* , a detailed examination of the cells and fibers) was made of its brain, in order to ascertain the exact amount of cortical or other nervous tissue which had been destroyed by the operation The amount of tissue which had been effectively destroyed was measured by means of a special technique, and when corrected for surface curvature this amount was expressed as a *percentage of the total area of cortex*

Procedures in Particular Tests. *Specific Habits* In the light-dark discrimination problem, which was used to test the learning of a *simple specific habit*, each subject was given food after he had passed through the lighted compartment into a side alley and was shocked

[1] If the number of trials necessary to relearn a habit is smaller than the number originally required to learn this habit, the difference is interpreted as evidence of memory for the habit

electrically when he passed into the darkened compartment The lighted compartment was sometimes on the right side, sometimes on the left, in irregular order, so that the rat would be unable to solve the problem merely by learning a simple "position habit" involving constant entrance into the same compartment For other rats, food was given after the rat passed through the darkened compartment, and shock was given in the lighted compartment The trials were continued until the rat succeeded in responding to the "correct" stimulus at least 80 per cent of the time

The same procedure was adopted in the intensity-discrimination problem to test the learning of a *more difficult specific habit* In this
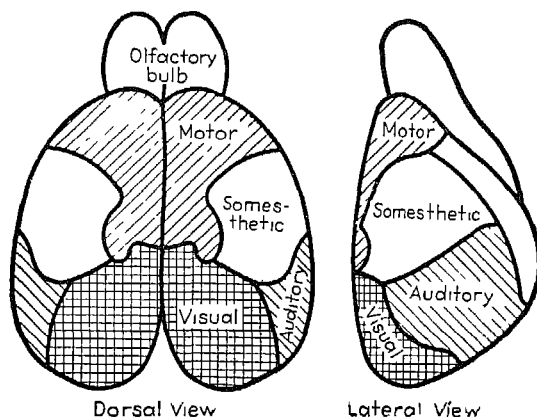
FIG 17 Schematic Views of the Rat's Brain to Show the Approximate Boundaries of the Projection Areas (*Adapted from Lashley*)

case, both compartments were lighted, with one light brighter than the other Certain rats were rewarded after each response to the dimmer light, and shocked after each response to the brighter light. For other rats the reverse procedure was used

The operated animals used in these specific-habit tests were deprived of given amounts of cortex within the "visual area" near the posterior pole of the cerebral hemisphere (see Fig 17) As controls, certain other subjects used on these tests were deprived of cortex in various regions outside the visual area [1]

[1] In other control groups, the destruction was effected in the subcortical neural center (*i e*, the lateral geniculate body of the thalamus) through which visual impulses from the retinas of the eyes reach the cerebral cortex

General Habits In the maze tests the normal and operated rats were made hungry and were given food at the end of each run through the apparatus The criterion of learning, *i e*, the test of mastery of the problem, was 10 successive errorless trials However, in the case of slow learners it was necessary to limit the number of trials given to any one animal This limit was 60 trials for Maze I, 100 trials for Maze II, and 150 trials for Maze III Both error and time records were taken for all maze trials

The operated animals used in the general-habit tests were deprived of different amounts of cortex, ranging between 1 and 50 per cent of the original total The operation was performed upon different parts of the brain in different individuals, so that each given locality on the surface of the brain had been removed in some of the operative cases

RESULTS AND INTERPRETATIONS

Specific Habits (Simple). In their *original learning* of the simple specific habit (the light-dark discrimination), all operated rats considered as a single group required 80 trials on the average, whereas normal animals required an average of 107 trials to learn this habit The operation on visual-area cortex certainly did not reduce the ability of rats to learn the specific habit used in this test

The superior performance of the operated animals *cannot be attributed to a real superiority in their ability to learn*, but rather must be attributed to the fact that operated rats typically are much less easily distracted by incidental stimuli (*e g*, noises coming from outside the apparatus) than are normal rats In other words, normal rats may be handicapped in simple problems by excessive response to such extraneous stimuli

In tests on the *retention* of this simple habit, rats which had learned the problem with intact brains were deprived of varying amounts of cortex in the visual area before they were retested These rats lost the habit as a consequence of the local operation In contrast, the learned discrimination persisted in animals in which *cortex anywhere outside the visual area* was destroyed following the original learning It is clear that although the *learning* of this simple "specific" habit was not impaired by any cortical injury, its *retention* was interfered with if the visual area of the brain was injured following original learning

Further tests, however, have shown that the retention of this habit is not greatly interfered with unless visual cortex which receives impulses from the visual thalamus (a subcortical structure) is entirely destroyed.[1] The visual cortex may, therefore, be regarded has having a localized function (*i e*, a *projection* function), in that it serves as the "cortical inlet" of the visual system. Hence, the area is essential for the retention of a habit which specifically requires visual control. However, it should not be hastily concluded that cortical tissue within the visual area possesses *only* the projection function.

Specific Habits (Complex). From the test of the brightness-discrimination habit, which is a more complex specific habit, somewhat different results were obtained.[2] The *original learning* of this habit was retarded by the destruction of cortex in the visual area, although the same operations did not retard the learning of the light-dark habit. (In control experiments, lesions *outside* the visual area did not impair the learning of the brightness discrimination.) For this habit, the greater the amount of cortex destroyed in the visual area, the more retarded was the learning. The correlation coefficient, which indicated the closeness of the relationship between *retardation* in the brightness habit and *amount of destroyed tissue*, was + 58. From this it may be inferred that when a specific habit is complex (*i e*, fairly difficult), the *amount* of intact cortex is also a factor which affects the speed of its acquisition.

Similar results were obtained for the *retention* of the brightness-discrimination habit, in that the greater the amount of the visual-area cortex which had been removed following the original learning, the greater the reduction in the animal's ability to perform the already learned habit. Injuries localized elsewhere in the cortex had no effect upon the retention of this habit.

So far as these specific (visual) habits are concerned, cortical tissue in the visual area is thus found to have, as at least one of its functions, a specific importance for the learning and retention of habits which

[1] Lashley, K S The Mechanism of Vision XII *Comparative Psychology Monographs*, 1935, vol 11, pp 43–79

[2] Lashley, K S The Mechanism of Vision II *Journal of Genetic Psychology*, 1930, vol 37, pp 461–480

are dependent upon visual control[1] Correspondingly, Wiley[2] has shown that the auditory area of the rat's brain (see Fig 17) is essential for the retention of simple habits which depend specifically upon auditory control, and that no other area of the cortex has this particular function.

In this connection it should be mentioned that the motor areas of the cerebral cortex possess a projection function which we may term the "motor-outlet" type When cortical tissue in this frontal area of the brain (see Fig 17) is destroyed, partial paralysis will occur There may also be incoordination in general activities, such as locomotion (as Maier[3] found), and the animal may be impaired in the retention of habits which specifically depend upon motor control (*e g* , a problem-box habit)

The possibility that the projection function may not be the only function of so-called "projection" cortex is supported by results from experiments such as that of Kirk[4] in which it was discovered that for rats, when a specific habit becomes very difficult (as when an F is to be discriminated visually from an Ⅎ), lesions anywhere in the cortex retard both learning and retention A comparable result for problem-box learning was obtained by Lashley,[5] who tested rats with varying degrees and locations of cortical destruction in their ability to learn a series of five problem boxes In each of these boxes the operation of a particular different type of latch fastener would permit the subject to escape from confinement and obtain food The cortically operated animals made poorer records than did normal animals on three of the five problems The degree of their inferiority in these problems was not significantly related to the *location* of cortical injury, but was found to be correlated with the *extent* of cortical lesion

[1] This statement is, of course subject to the reservation that the original learning of very simple visual habits, such as the light dark habit, does not appear to be affected by visual area injuries, although their retention is affected by such injuries

[2] Wiley, L E The Function of the Brain in Audition *Journal of Comparative Psychology*, 1932, vol 54, pp 143–172

[3] Maier, N R F The Cortical Area Concerned with Coordinated Walking in the Rat *Journal of Comparative Neurology*, 1935, vol 61, pp 395–405

[4] Kirk, S A Extra striate Functions in the Discrimination of Complex Visual Patterns *Journal of Comparative Psychology*, 1936, vol 21, pp 145–158

[5] Lashley, K S Studies of Cerebral Function in Learning XI The Behavior of the Rat in Latch Box Situations *Comparative Psychology Monographs*, 1935, vol 11, pp 5–42

The relationship between an inferior performance in the problem situation and the amount of cortex lost was indicated by correlation coefficients ranging between + 48 and + 72 The significance of this fact will become evident in the subsequent treatment of results for "general" habits

General Habits (Simple and Complex). In *learning* maze habits operated rats were always significantly retarded as compared with normal rats For instance, in learning Maze III, normal rats required an average of 19 trials, whereas operated rats required an average of 91 trials, and the error totals of all operated rats were significantly

TABLE I

The Relation between the Percentage of Cortex Destroyed and the Number of Errors during Learning

Per cent of cortex destroyed	Average total number of errors committed in learning (4–11 rats per group)		
	Maze I	Maze II	Maze III
0 (normals)	[1] 7 3	[1] 16 2	47 4
1–10	6 6	15 4	72 0
11–20	7 2	40 0	266 0
21–30	31 8	43 5	396 0
31–40	29 3	63 2	485 0
41–50	34 7	52 8	580 0
50+	40 0	66 6	1446 0

[1] The operated animals obtain an artificial advantage in these error averages in that Mazes I and II were not learned in certain cases within the training limits, which were set too low

greater than were the error totals of normal rats For the three mazes, a comparison of the results for the various groups of normal and of operated rats may be made from Table I

It is evident from these results that the retardation in original learning was greater, the larger the amount of the cortex which was injured That *the amount of cortex lost is the condition which determines retardation in complex learning* was indicated by a correlation coefficient of + 75 between amount of destroyed cortex and the degree of retardation in maze learning On the other hand, in the learning and retention of general habits, the locus of destroyed cortex appears to be of indifferent importance

The last point, that the ability to learn and to retain general habits

depends upon the amount of intact cortical tissue, is particularly emphasized by a comparison of the results for the three mazes It will be recalled that Maze I was designed to be a relatively simple problem, Maze II to be intermediate, and Maze III to be the most difficult. From an examination of Table I it becomes apparent that the operated rats in any given group had less difficulty in learning Maze I than in learning Maze II and clearly had their greatest difficulty in learning Maze III For instance, rats which had lost 50 per cent or more of their cortex learned Maze I with an average total of 40 errors but committed 1,446 errors on the average in learning Maze III In further studies by other investigators, general problems of great difficulty (or very difficult specific habits) have been presented to rats with extensive cortical destructions, and the subjects have been totally unable to make any progress in learning the required habits This reminds us of the fact that human idiots and imbeciles are limited to the acquisition of very simple habits, and that such individuals are completely unable to cope with problems which are easily solved by other individuals

The above results were substantially duplicated in *retention* tests on maze habits which had been learned prior to cortical operation The extent to which the operations interfered with retention was greater, the greater the amount of the cortex which was destroyed after original learning had occurred Here also, the location of the injury was of no detectable importance, the extent of the injury was the essential factor. These results thus support the previous findings in showing that the correlation function (*i e*, the general associative function) is nonlocalized with respect to brain areas

Investigation of the Specific-pathway or "Storage-center" Hypothesis of Nervous Changes in Learning. It is a popular theory of learning that what is acquired is "stored" in certain parts of the brain, even in particular brain cells This assumption is sometimes found in psychological treatments of learning, in the form of assertions that the process of mastering a habit occurs by effecting changes in specific pathways in the brain, and that after learning has occurred, given neurones have the particular function of carrying the impulses which appropriately arouse the learned movements

Two features of Lashley's experiments are sufficient to weaken materially, if not to destroy, this view First, it will be recalled that

a given injury (*e g* , destruction of 30 per cent of cortex) had the same effect upon a general habit, regardless of where the cortex was destroyed The neural changes effected by the maze habit were definitely not "stored" in particular parts of the brain, but apparently involved living tissue throughout the brain Second, in experiments with animals which had learned Maze III, Lashley disconnected the various areas of the brain in different cases by means of long or short cuts through the brain tissue Thus, in one experiment or in another, all of the possible tracts of association fibers which might conduct impulses among the different brain areas were severed, but only negligible amounts of cortex were destroyed After their recovery, these animals were tested, but they did not show any retardation in the habit Since this result is good evidence that the neural changes essential to a given habit are not restricted to arousal through any particular fiber pathways, Lashley concludes that correlation cannot be " expressed in terms of connections between specific neurones "

Discussion

The results of Lashley's experiments on *specific habits* agree with the findings of other investigators in showing that the brain possesses a "projection" function which is localized in given areas Thus, the retention of the light-dark discrimination habit was impaired by injuries anywhere within the visual area, but injuries to cortex outside of the visual area had no effect upon retention of this habit In a recent study, Lashley has shown that this simple specific visual habit is lost entirely when the visual cortex which has fiber connections with the visual thalamus is entirely destroyed From the results, it is reasonable to conclude that the projection functions of certain cortical areas (the visual, the auditory, the somesthetic) consist in the fact that through certain layers of neurones in these "sensory-inlet" areas, impulses from the corresponding sensory systems (*i e* , the related sense organs and subcortical nervous centers) gain access to the cortex The case appears to be similar for the "motor-projection area," as the center through which cortical impulses are discharged to lower centers of the nervous system

The *retention* of the light-dark discrimination habit was not impaired by cortical destructions outside the visual area, apparently

because in the case of a simple habit of this specific type the correlation function is required only to a minor extent As has been said, this fact contrasts with the finding of Lashley and others that rats which have learned very difficult specific habits (*e g*, pattern-vision habits) are impaired in their retention of the habit, whether the cortical injury lies within or outside the visual area Furthermore, the discovered habit impairment is greater, the larger the extent of the cortical injury Such results show that for efficient performance a habit which is sufficiently difficult involves all uninjured brain areas, regardless of whether the habit is specific or general in its sensory control This suggests the existence of a second cortical function which has essential importance for intelligence

In the case of a *general habit*, such as the maze habit, the greater the amount of cortex removed, the less efficient are rats in their learning and in their retention of the habit Furthermore, since for different animals the injury of equal amounts of cortex in different parts of the brain produces equal retardations in the learning or retention of the maze habit, the cortex as a whole (or all intact cortical tissue) is essential for most efficient learning, and no particular area is more important than is any other area *Intelligence, defined as the capacity for modifiable behavior, may therefore be regarded as a function of the entire cortex* This, substantially, is the meaning of Lashley's *theory of mass action*

A brief reference to the anatomical relations of the brain areas will give further point to these remarks Each of the sensory-projection areas (*e g*, the visual area) is connected by fiber tracts with a correspondingly different part of the thalamus, and through these cortical areas the respective sensory systems discharge impulses into the cortex Thus, the projection area in question (*e g*, the visual area) has a specific importance for a habit which requires one *specific* type of sensory control, as visual control is required for the light-dark habit Extensive destruction of cortex within the particular projection area will thus impair or prevent the performance of the corresponding specific habit On the other hand, destructions outside the given projection area have no noticeable effect if the habit is very simple In contrast, when a habit is complex and difficult, regardless of whether it is specific or general in its sensory control, the destruction

of *any* part of the rat's cortex impairs its performance[1] *The projection function is localized, whereas the correlation function is nonlocalized The entire cortex, including the projection areas (which thus have two functions), participates in the correlation function* This, apparently, rests upon the fact that all parts of the cortex are interconnected in every conceivable way by tracts of "association" fibers the cell bodies of which comprise the bulk of the cortex itself The different cortical areas are termed "equipotential" with respect to the correlation function, since in this function they participate similarly and with approximate, if not complete, equality in their importance.

Lashley believes that his conclusions as to the relation of cortical tissue to intelligence (*i e*, general capacity for learning) in rats may be applied to all animals which possess cortical tissue "*Data on dementia in man,*" he says, "*are suggestive of conditions similar to those found after cerebral injury in the rat*" That is to say, by actually destroying considerable amounts of cortical tissue in rats, Lashley produced rats which, in their greatly reduced intelligence, were equivalent to human individuals who become reduced in intelligence because of nervous degenerations occurring at some time after birth Perhaps the comparison may be extended to include *amentia* (*i e*, feeble-mindedness) as well The principal difference is that in the case of human amentia, the defective intelligence is attributable to a nervous equipment which is inadequate for learning, not because of tissue destruction or deterioration but apparently because of fundamental shortcomings in the original development of the individual

Although various objections have been raised to applying the mass-action theory of intelligence to man, the effectiveness of such objections is materially reduced by the fact that they are not based upon thoroughgoing investigations comparable to those made upon the rat For instance, one criticism is based upon the finding of clinical

[1] An effective demonstration of correlation function in the tissue of the visual projection area of the brain has been accomplished by Tsang, who blinded a group of rats in their infancy, then tested the animals as adults in the maze In these animals, destruction of the cortical visual area at a time well before the maze tests resulted in a marked decrease in maze-learning ability This decrease was much the same as was obtained from normal sighted rats after equivalent brain operations but was considerably greater than that shown by blinded rats with intact brains (Tsang, Y The Functions of the Visual Areas of the Cerebral Cortex of the Rat in the Learning and Retention of the Maze *Comparative Psychology Monographs* 1934, vol 10, pp 1-56, *ibid*, 1936, vol 12, pp 1-41)

neurologists that the degeneration of tissue within certain local areas of the cortex in man generally is accompanied by correspondingly different disturbances in language function (*i e*, *aphasia*) Those who object to applying the mass-action theory report themselves unable to understand how, according to that theory, a certain brain area could become more important than others for the control of a generalized language function in the individual However, because of the relatively uncontrolled conditions under which the human evidence is gathered, it is quite possible that the results of injuries in projection areas (which we know are marked by particular kinds of defects, specifically sensory or motor in nature) have been stressed at the expense of the unrecognized or less apparent general retardations produced also as a result of these and other cortical injuries It is unfortunately true that the evidence which is presented in the literature on aphasia is confused and, therefore, contributes little at present to the solution of the problem of brain function

On the other hand, it should be mentioned that many contemporary investigators of aphasia have indicated their skepticism concerning the validity of any strict "cortical-localization" view of aphasic disorders Thus in a leading source book on the subject, Weisenburg and McBride[1] have offered a classification of the principal types of aphasia which reduces the list essentially to *receptive*, *expressive*, and *mixed* aphasic patterns Such a view involves no essential contradiction of the discussion of cortical function offered in the present chapter, since "receptive" types of aphasia may be interpreted as cases in which specific sensory-projection factors *predominate*, "expressive" types as cases in which motor-projection factors *predominate*, and "mixed" types as cases in which qualitatively different cortical functions are involved, not identifiably sensory or motor and frequently with a heavy emphasis upon what we have called "correlational" (*i e*, organizational) function [2]

[1] Weisenburg, T, and K E McBride *Aphasia* New York, Commonwealth Fund, 1935

[2] Lashley recently has reported experiments in which attempts were made to produce in monkeys a specifically "receptive" type of difficulty which is somewhat comparable to the traditional "visual agnosia" (*i e*, failure of perceptual recognition of objects) by destroying the portions of the prestriate (visual) cortex most likely to have visual-associative functions Specifically, the destroyed areas of cortex were those which corresponded most closely in their anatomical relations to the areas which have been thought responsible

The fact that under proper training procedures aphasic patients can regain their language and symbolic functions or can improve greatly in these functions shows that the psychological effects of damage to the various alleged "language areas" in the human brain need not be permanent These results encourage caution against any dogmatic adherence to an oversimplified view of "strictly localized" cortical functions and suggest that the "equipotentiality principle" of brain function may apply even in connection with the cortical control of language functions in man [1] [2]

Perhaps the generalized (*i e*, the correlation) function of the human brain will remain obscure until adequate tests of the patient's learning and thinking capacity are made *before* a brain injury occurs, are repeated *after* the brain injury reaches its height, and the study is completed with a thorough investigation of the condition of the brain after death Until we have made as careful and thorough a study of man or some other higher primate as Lashley and his collaborators have made of the rat, dogmatic conclusions are unwarranted. It is better to leave the question open for the present, so far as man is concerned However, we should not forget the probability that a line of evidence which has thrown light upon the nature of cortical function in one mammal may do the same for the others, which also possess cerebral cortex

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for "visual agnosia" in man However, in a variety of postoperative tests the subjects were not found inferior to normal subjects in their recognition of objects, of form and movement, of distance, and of color The experimenter found only that the cortically operated monkeys showed "some deterioration of higher level functions which are doubtfully visual, and this not consistent for all animals " (Lashley, K S The Mechanism of Vision XVIII Effects of Destroying the Visual "Associative Areas" of the Monkey *Genetic Psychology Monographs, 1948, vol 37, pp 107-166*

[1] Granich, L *Aphasia A Guide to Retraining* New York, Grune and Stratton, 1947

[2] Halstead, W C *Brain and Intelligence* Chicago, University of Chicago Press, 1947

CHAPTER XI

ORGANIC NERVOUS DISEASES IN RELATION TO BEHAVIOR

INTRODUCTION

Physiologists and psychologists have long known that it is the nervous system which makes integrated behavior possible, and that a sound nervous system is a prerequisite for the proper functioning of the entire human being Thus, a healthy nervous system is essential to the normal operation of *the vegetative processes*, such as digestion, respiration, circulation, and excretion, *the sensory-motor processes* (sensation and movement), and *the so-called "higher" or "mental" processes*, such as thinking, intelligent action, adjustment to the social environment, and the like. For this reason disturbances in the functioning of the nervous system may cause serious abnormalities in behavior

Injury or disease of the vegetative (*i e*, the autonomic) nervous system may be revealed in various kinds of malfunctioning, mainly of the viscera, which manifest themselves in numerous disorders of the glandular, vascular, respiratory, genitourinary, and gastrointestinal systems Sensory-motor disturbances derive from disorders of the cranial and peripheral nerves, the spinal cord, the brain stem (*i e*, medulla, pons, midbrain, basal ganglia), the cerebellum, and the cerebrum Such disorders are revealed in sensory disturbances and in disturbances in the integrated and balanced action of the various motor organs of the body Personality disorders and disturbances in memory, sequential thinking, social adjustments, and the like are associated primarily with the malfunctioning of higher brain centers, in particular, of the cerebral cortex, whether this malfunctioning be due to disease, injury, or some other cause

The initial problem of the neurologist is to determine the locus and nature of the disturbance in the nervous system This *diagnosis* is based upon the concrete behavior abnormalities (*i e*, the *symptoms*) which he observes in the individual patient After the diagnosis has

been made, the neurologist is generally in a position to cope with the problem of treatment and cure

It has frequently been said of neurology that no other branch of medicine lends itself so well to the correlation of symptoms with the diseased structures underlying them Nevertheless, the neurologist must exercise the greatest thoroughness and care First, he must adequately observe and record important aspects of the patient's behavior, such as the nature and distribution of reported pain, the existence of anesthetic areas, abnormalities of the reflexes, disturbances of gait, posture, and speech, and disorders of emotional and intellectual responses In the second place, he must obtain a complete "case history" This consists of a family history and an account of the patient's previous life, of the mode of onset of the symptoms, and of the course and development of the illness A correct diagnosis requires a proper evaluation both of the patient's history and of his symptoms For the adequate performance of this task the neurologist should be trained both in the medical sciences and in psychology

In what follows, a brief account will be given of the pathology and symptoms of a few important disorders of the nervous system[1] Behavior disorders for which no organic basis is known will not be treated in this chapter

ACUTE ANTERIOR POLIOMYELITIS (INFANTILE SPINAL PARALYSIS)

Pathology. Infantile spinal paralysis is an intense inflammation which is almost wholly limited to the *ventral* (*i e*, the anterior) *horns of the spinal cord*, the region of the gray matter of the cord which contains the cell bodies of peripheral motor neurones The pathology of the disease can be followed by referring to Fig 18 The inflammatory process typically attacks the ventral-horn cells at certain levels of the spinal cord and destroys these cells more or less completely In certain cases, both the left and right ventral horns of a given level are affected, in other cases, the disease is confined to only one side of the cord When both sides are involved, the disease process is usually asymmetrical, that is, it affects one side more seriously than it does the other The inflammation causes the afflicted

[1] Of the several textbooks of clinical neurology which have been consulted, the one most utilized in the descriptions of the nervous diseases discussed below is Wechsler, I S *Textbook of Clinical Neurology*, 6th ed Philadelphia, Saunders, 1947

motor cells to swell, and if the inflammation is severe, these cells presently disintegrate and disappear. The *degeneration of the cell bodies is followed by that of the associated processes* (axones and dendrites), since no nerve fiber can continue to live after its cell body has been destroyed. Subsequently these neurones are replaced by connective-tissue cells. In the course of time there is an *atrophy* (*i e*, a shrinkage) *of the ventral* (motor) *roots* of the spinal nerves on the levels of the cord which are affected. This atrophy results from the disappearance of the axones, the cell bodies of which, before they were
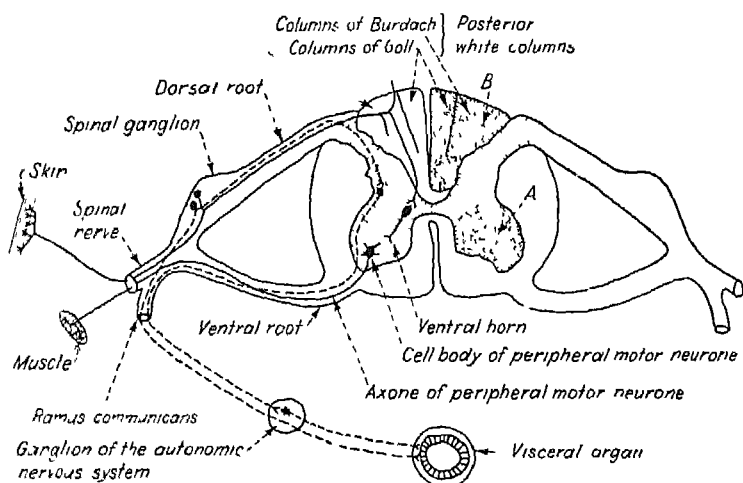
Fig. 18 Diagram of a Cross Section through the Spinal Cord, Showing the Neural Elements Most Commonly Affected in A, Acute Anterior Poliomyelitis (Infantile Spinal Paralysis), and in *B*, Tabes Dorsalis

destroyed, lay in the ventral horns of the gray matter. The *spinal nerves* also *atrophy* extensively because of the degeneration of the axones which formed their motor component. Similarly, there are changes in the muscle cells on which the motor neurones terminated when these neurones were intact. The *muscle cells* of each muscle which these neurones supplied *dwindle in size and weaken* as a result of disuse (since they cannot be aroused to a state of contraction by neural action), and also because these cells develop trophic (*i e*, nutritional) disturbances. Therefore, *each affected muscle as a whole undergoes a process of degeneration*. Occasionally the inflammation

spreads up the cord and involves the motor nuclei of certain of the cranial nerves, in which case there may be paralyses of the ocular, facial, and tongue muscles, with difficulties in swallowing. The meninges[1] also may be somewhat affected If the inflammation destroys the respiratory and cardiac centers in the brain (specifically, in the medulla oblongata), the patient dies.

Infantile spinal paralysis occurs mainly in epidemics, although "sporadic" cases also happen It is primarily an affliction of childhood. It is most common between two and four years, and is practically unknown in infants younger than six months But adults are sometimes stricken, and when they are, the form of the disease is usually more severe than it is with children, the mortality rate is higher, and the degree of recovery of function considerably less After one attack, there is usually immunity, but cases of reinfection sometimes occur

It has been ascertained that the cause of the disease is a filterable virus which so far has proved highly resistant to destruction The virus enters the body by way either of the nasal passages or of the gastrointestinal tract and may be transmitted through the saliva or the nasal secretions, through the stools, or possibly through an intermediate host (*e g* , flies) It is claimed that a recent tonsillectomy may predispose to the disease, especially in the form of high spinal and cranial nerve involvement

Symptoms. After an incubation period of 2 to 10 days, the disease proper is usually preceded by a *short prodromal* (*i e* , preliminary) *period* [2] The main symptoms of acute anterior poliomyelitis may be discussed under five headings

1. The initial muscular weakness rapidly increases and within a

[1] See description of the meninges and Diagram *B* of Fig 21 on p 199

[2] The *prodromal period*, when it occurs, lasts from a few hours to a few days Its characteristics vary considerably so that it often passes unobserved or is mistaken for a mild general infection The patient may show any of several symptoms (such as a slight degree of fever, poor appetite, vomiting, diarrhea, redness of the throat, coughing, headache, restlessness, or drowsiness), or he may complain of vague pains in the limbs or at the back of the neck

Following the prodromal period, one to several days may elapse with the patient apparently well This, however, is followed by a *meningeal period*, signaling the onset of the spinal disease At this time the mild inflammation of the membranes covering the spinal cord (see Fig 21, Diagram *B*) may cause some rigidity of the neck and generally an exaggerated sensitivity

few hours or a few days the maximum of *paralysis* for the given case is reached. Since neural impulses cannot reach the muscles of which the pathways of innervation have been destroyed, the paralysis is of a *flaccid* (soft and limp) type. The muscles are "lumpish" and lacking in tonus. The paralysis usually invades a large group of muscles, generally of the extremities. Thus, a limb or a part of a limb may be paralyzed, or one arm and one leg, both legs, both arms, or even all four limbs. The precise region of the paralysis is always determined by the location of the diseased nervous tissue. If, for example, the paralysis is limited to a leg, one can infer that the destructive process was confined to the lumbar[1] section of the cord and to only one side of the cord, the side of the paralyzed leg. The muscles of the back may be affected and, more rarely, the neck muscles. Occasionally the abdominal muscles are paralyzed. As has been pointed out, when the disease process extends to high spinal levels and to certain cranial nerve nuclei, there may be paralyses of the diaphragm, and of the eyes, face, and tongue. The patient dies if the centers of the cranial nerves controlling breathing and heart action are destroyed. After the maximum degree of paralysis has been reached (usually only 24 to 48 hr. after the onset of the disease proper), the inflammatory process begins to abate and the disturbed functions begin to improve. The degree of improvement possible depends of course upon the number of neurones in the affected parts of the nervous system which were not irreparably damaged by the disease process.

2. The *reflexes* (*e.g.*, knee-jerk and ankle-jerk) which are exhibited by healthy limbs *disappear in the paralyzed members*. This loss is due to the fact that the motor component of the reflex arc has degenerated and is therefore nonfunctional.

3. All through the acute stage of the illness, *pains* are frequently reported, especially when the affected parts of the patient's body are passively moved by an attendant. The patient also commonly shows a general *hypersensitivity*.

4. In a short time, the *paralyzed muscles* begin to *shrink in size* because of trophic disturbances and lack of exercise. This muscular

[1] The *lumbar section of the spinal cord* is the region which gives rise to the spinal nerves 21 to 25 inclusive. (In all there are 31 pairs of spinal nerves which are numbered consecutively from those nearest the head to those farthest from it. For further information about the spinal nerves see footnotes 1 and 2, p. 202.)

atrophy is progressive, as may be seen clearly by comparing the healthy with the paralyzed limb of a crippled adult who was stricken in childhood with anterior poliomyelitis

5 Subsequent to the disease, but associated with the paralysis, there frequently occur a *stunting of the bone growth* in the affected parts, *changes in the joints and circulation*, and *deformities* The characteristic gait of many who have been afflicted with infantile spinal paralysis derives from inequality in the length of the legs due to atrophy of the bones in the paralyzed one The deformities arise also from the overaction of healthy muscles which are unopposed by their paralyzed antagonists

Prognosis[1] and Treatment. About 5 to 10 per cent of the cases, especially those with laryngeal, pharyngeal, cardiac, and respiratory symptoms, die during the active phase of the disease Mild cases recover fairly rapidly, the acute symptoms ordinarily subsiding after a week or two As has been said, the maximum damage is shown in the paralyses present after the acute stage has passed Then begins the gradual process of recovery, which may continue up to two years or longer, depending both on the severity of the original inflammation and on the intelligence and skill with which the case is managed The final recovery may be partial or, as in the majority of cases, complete, *i e* , without residual paralysis

Various medical treatments are applied both to alleviate the symptoms and to combat the disease process during its active phase Protracted rest in bed is considered very important In the attempt to reduce the paralysis, warm applications, gentle massage, and passive movements are started almost immediately after the very acute period has subsided, although the patient must be restrained from walking or using his limbs too soon or too energetically Warm baths are also given

It is frequently true that, although most of the cells have been destroyed in the ventral horns at a given level of the cord, a certain number of cells remains intact It follows that, although the degeneration of the greater part of the motor cells has caused the paralysis of a muscle or a group of muscles, some individual muscle fibers or even some small muscles in the affected group can be made to contract through the agency of such motor neurones as may have escaped

[1] A "prognosis" is a prediction of the probable course and outcome of a disease

permanent injury By means of appropriate tests, the physician is able to detect the presence of those incomplete activities of which the afflicted muscles may still be capable On the basis of such an analysis, when the patient is adjudged ready for it, he may be "reeducated" in the performance of certain movements by practicing them separately and persistently under medical guidance Such practice can be undertaken under recreational conditions (*e g.*, swimming in a warm water pool, bicycling), or in an occupational or creative work situation (as in working the treadle of a sewing machine, weaving, etc) In this way, also, the atrophy of muscles (chiefly as a result of disuse) may be markedly reduced But enormously valuable as such reeducational methods are, they of course cannot restore functions which depend on the integrity of tissues that have been permanently destroyed Therefore, although the functions of a severely afflicted limb may be largely recovered through reeducational techniques, the limb may never regain its full capacities

In the effort to minimize or avoid deformities, light braces and supports are sometimes used Orthopedic operations in the treatment of deformities are now far less frequently performed than they formerly were Since recovery of function, especially under a program of guided exercise, may continue for as long as 2 years after the acute attack, such an operation, even if desirable, should not be performed before the end of that period

SYRINGOMYELIA

Pathology. Syringomyelia is a chronic, slowly progressive disease which involves principally the spinal cord, but frequently also all of the central nervous system anterior to the spinal cord, except the cerebrum and the cerebellum The pathologic process (see Fig 19) consists in the *development of a cavity* (syrinx) *or cavities which form around the central canal of the cord* The result is a *destruction of those neural elements which lie close to the central canal in the gray matter of the cord* Hence, *the earliest seat of destruction is the pain and temperature fibers which cross to the opposite side of the cord via the anterior commissure* (adjoining the central canal) to form the long ascending lateral spinothalamic tracts The destruction of the pain and temperature pathways is limited to the vicinity of the cavity Then, as the destruction advances, the cavity becomes larger and

encroaches upon the *ventral motor horns of the gray matter of the cord*. The pathologic process usually first attacks the cord at its upper levels, in the cervical enlargement.[1]

Subsequently, the destruction may take many forms. But the resulting abnormalities in behavior are always closely correlated with the location, extent, and form of the cavity or cavities. A given syrinx may extend up and down the cord through a great many segments. It may reach the medulla and include the nuclei of certain cranial nerves. It may progress dorsally and cut through the posterior white columns, thus interrupting the route for afferent impulses from
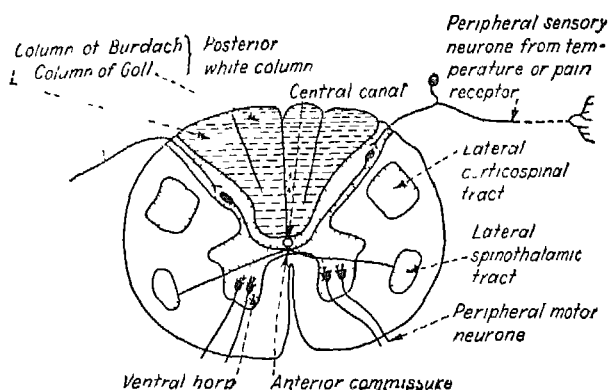
FIG. 19. Diagram Showing the Location of the Tracts of the Spinal Cord Most Commonly Involved in Syringomyelia

kinesthetic and tactual receptors which are situated below the region of destruction. It may extend laterally and destroy the lateral corticospinal pathways, so that descending impulses from the motor area of the cortex can no longer reach the motor cells of the spinal cord. But the essential feature of the disease is a combination of (1) destruction of the pain and temperature fibers in the anterior commissures of certain segments of the cord, and (2) destruction of the ventral horns of approximately the same segments.

The cause of syringomyelia is not known, but it is thought to arise

[1] The cervical enlargement is a relatively thickened portion of the spinal cord. It extends from the point of emergence of the fourth cervical nerve to that of the second thoracic nerve, inclusive. (The positional relationships of the several divisions of the spinal nerves are described in footnotes 1 and 2, p. 202.)

from a congenital neural defect which is revealed by abnormality in the development of the central canal of the spinal cord The disease usually afflicts adults and may drag on for 30 years or longer

Symptoms. Since the pain and temperature fibers of a limited segment are almost always the first to be affected, the earliest symptom is generally a *loss of pain and temperature sensations in the skin areas corresponding to the diseased level of the cord* These affected areas of the skin are usually restricted at first to the fingers, hands, and arms They commonly occur on both sides of the body, *i e* , on both arms, since the anterior commissures contain fibers which cross from the left side of the body to the right spinothalamic tract, and fibers which cross from the right side and pass into the left spinothalamic tract In most cases, tactual sensitivity is unimpaired The blindfolded patient can tell, for example, that he is touching a radiator but not that the radiator is hot In the beginning, the patient is characteristically unaware of the decrease in sensitivity, so that he frequently is scalded, burned, bruised, or cut without knowing it A marked lateral extension of the syrinx affects the long pain and temperature fibers of the spinothalamic tracts When this lateral extension occurs on one side only, the result is a *Brown-Séquard sensory disturbance* (loss of pain and temperature for the whole body below the level of the syrinx), limited to the side opposite to that of the syrinx, in addition to the loss of sensitivity in the affected segments on both sides of the body

Associated with the neural disorders, there are *trophic and circulatory disturbances* in the affected parts The latter disorders are responsible for the bluish or reddish appearance of the skin and probably underlie the patient's complaints of numb, tingling, and cold sensations in the involved areas

The chief motor symptoms result from the slow process of destruction of the ventral horns These symptoms are, first, *erratic twitchings and tremors* of muscles or parts of muscles (usually in the fingers and hands), and then *paralysis and atrophy* (the gradual process of muscular wasting as a result of lack of exercise) In time, the atrophy may extend to the arms and shoulders The affliction of the ventral horns in syringomyelia produces the whole complex of symptoms which are typical of acute anterior poliomyelitis If the lateral corticospinal tracts are involved, the muscles of the body below the corticospinal

lesion become paralyzed. This paralysis is not a soft and flaccid one, accompanied by atrophy (as is the case in all afflictions of the ventral horns), but a *spastic* (*i. e.*, stiff and rigid) *paralysis* in which there is no atrophy. The neurological ground for the difference in the character of the paralyses resulting from damage to the ventral horns (*lower motor-neurone paralysis*) and from corticospinal tract lesions (*upper motor-neurone paralysis*) is not entirely understood.

Fig. 20. A Case of Syringomyelia.

The patient shows the muscular atrophy which results from afflictions of the ventral horns of the spinal gray matter. (*Courtesy of Dr. L. I. Lyons, New York.*)

Prognosis and Treatment. As far as cure is concerned, the prognosis for syringomyelia is unfavorable. In certain cases, the symptoms remain unchanged for a long period of time, so that the course of the disease seems to be arrested. But, characteristically, the

disease progresses slowly, the symptoms increase in severity, and the patient becomes more disabled as the paralysis grows. If the cranial nerve nuclei which are found in the medulla oblongata are afflicted, there result such disturbances as tremors of the tongue and facial muscles, atrophy of the tongue, paralysis of the muscles which control eye movements, difficulty in swallowing, regurgitation, and paralysis of one or both vocal cords If the cavities involve areas of the nervous system which control the functions of the intestines and bladder, or if the cardiac or respiratory centers in the medulla oblongata become seriously involved, death soon ensues Syringomyelia may last 20 or 30 years or even longer, with the patient finally succumbing to some complicating disease (*e g*, pneumonia, tuberculosis) which he is especially liable to contract because of his general condition of debility.

As regards treatment, there is no known remedy which will arrest the development of the disease, although good results have sometimes been reported from the application of X rays to the spine at the level of the syrinx Spinal surgery has occasionally been performed for the purpose of facilitating such X-ray treatment and also in order to evacuate the syrinx The symptoms are treated as they arise The trophic disturbances and the paralysis are treated as in infantile spinal paralysis, but for the sensory losses no remedial measures are known.

MENINGITIS

Pathology. Meningitis is an *inflammation of the meninges* (*i e*, membranes or coverings) *of the brain or cord, or both* Figure 21 presents diagrams of these membranes in relation to the brain and to the spinal cord Three membranes cover the brain and spinal cord over their whole extent, these are the *pia mater* (closest to the brain or cord), the *arachnoid*, and the *dura mater* (the outermost of the three) The pia and arachnoid lie very close together, but they are separated by a space (the subarachnoid space) in which the cerebrospinal fluid circulates This space is continuous with the four ventricles (*i e*, cavities) of the brain, which are situated deep in the brain tissue Thus, just as the meninges form one continuous structure, the subarachnoid space and the brain ventricles constitute a single communicating system within which the cerebrospinal fluid is contained It follows that an acute bacterial inflammation which starts anywhere along the membranes is apt to spread throughout

their entire extent Any one of a variety of agents may be responsible for the inflammation, but the signs and symptoms of a meningitis are much the same, irrespective of the causative factor The symptoms depend chiefly on the locus and extent of the nervous tissue affected, and less clearly on the specific type of invading organism (whether
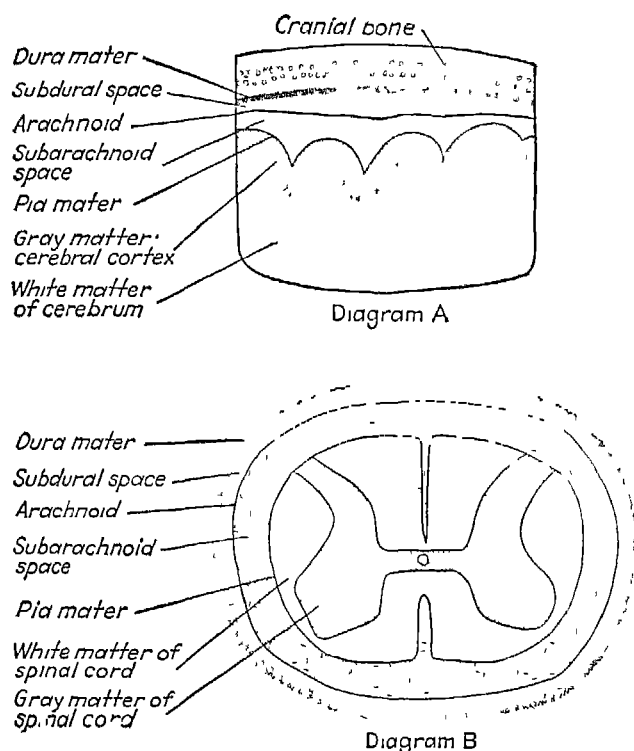
FIG 21 Diagrams of the Meninges

Diagram A Frontal section through the skull, meninges, and brain
Diagram B Cross section of the spinal cord and meninges

meningococcus, tubercle bacillus, or some other agent) When the meninges are invaded by organisms and their toxins, there is an inflammatory reaction in which many of the bacterial products are poured into the subarachnoid space, with a resulting increase in the volume of the cerebrospinal fluid Almost always, one can find an early increase in the amount and pressure of the cerebrospinal fluid

and can detect the presence of microorganisms within it The best means of determining both the occurrence and the type of meningeal infection is by an examination of the cerebrospinal fluid, which is obtained by a puncture of the spine This puncture is usually made in the lumbar[1] region

Symptoms. *Headache*, the earliest symptom of the disease, is thought to be due to the increased pressure exerted on the brain by the cerebrospinal fluid *Dizziness* and *vomiting* frequently appear in association with the headaches

Perhaps the most important single sign of meningitis is stiffness or *rigidity of the neck*, which probably is due to the inflammation of the meninges at the base of the brain This rigidity of the neck appears very early, is an almost invariable symptom, and increases as the disease progresses In certain forms (e g , epidemic cerebrospinal meningitis), *the neck is* actually *stretched backward* to a marked degree The patient reports acute pain if the leg is extended at the knee or flexed at the hip (*Kernig's sign*), this arises from the inflammation of lumbar and sacral roots and meninges Another peculiar symptom is *Brudzinski's sign* the patient lies on his back and the physician bends the neck forward on the chest, the result is an involuntary flexion of the legs at the knee and hip joints, so that both legs become flexed upon the thighs and the thighs become flexed upon the abdomen Still another symptom is a *convulsive posture*, characterized by arching of the body backward so that the patient rests on head and heels This sign appears relatively late in the course of the disease

In every patient there are *signs of irritation of the motor apparatus* These range from *muscular twitchings and spasms*, *cramps*, *tremors*, and the like, to *generalized convulsions* In addition to these marks of irritation of the motor system, there are *paralytic phenomena* which occur later than the foregoing signs These paralyses result from the involvement of the motor cortex, they are spastic (*i e* , stiff and rigid) in type and may be very extensive or may affect only limited groups of muscles

As the disease begins to involve the cranial nerves at the base of the brain, new disturbances appear A *paralysis of the eye muscles* (both internal and extrinsic) is revealed, first by *irregularity in the*

[1] See footnote 2, p 202

size of the pupils, later by sluggish pupillary reaction, and finally by complete *loss of pupillary reflexes* *Cross eyes*, *squint*, and *double vision* are also common

Fever is another very early and very constant symptom, it is low in certain forms of meningitis and high in others A *slow pulse* is often the result of irritation of the vagus center (inhibitory to heart action) in the medulla

A *hypersensitiveness to visual, thermal, tactual, and auditory stimuli* is common, it is undoubtedly due to irritation of the sensory cortex and of the nuclei of the optic and acoustic nerves

Rashes and *skin eruptions* are frequently present

So-called *mental symptoms* are almost invariable in meningitis Early in the disease, these consist of restlessness, irritability, apathy and drowsiness The more serious symptoms which occur later are delirium, insomnia, stupor, and coma

Associated with these signs and symptoms are many others which occur more or less commonly in meningitis But for a general diagnosis of the disease, the especially significant early signs are headache, neck rigidity, vomiting or a convulsion, fever, and the Kernig sign Such a picture calls for an immediate puncture of the spine for an examination of the cerebrospinal fluid, in order to determine the specific cause of the meningitis so that proper treatment can be initiated

Prognosis and Treatment Any one of a number of agents may be responsible for an acute meningitis (*e g*, the meningococcus, the pneumococcus, streptococcus, tubercle bacillus, syphilis spirochete) Both the prognosis and the course of treatment of each case depend upon the nature of the specific causative factor

In the past the treatment of acute meningitis, for the most part, was unsatisfactory and often futile The mortality was very high complications were frequent, and in those who recovered permanent defects (*e g*, gait disturbances, noises in the ears, deafness, cross eyes, mental deficiency) were fairly common At present, although tuberculous meningitis still does not respond to treatment, almost all other types do, and therefore are considered much less grave conditions than they formerly were Epidemic cerebrospinal meningitis, caused by the meningococcus, now is successfully treated by the prompt and vigorous use of the sulfonamides (sulfathiazole and sulfadiazine,

usually the latter) Other types, especially pneumococcus meningitis, yield more easily to penicillin therapy.

TABES DORSALIS (LOCOMOTOR ATAXIA)

Pathology. Tabes is a chronic progressive syphilitic disease of the nervous system. An understanding of the pathology may be facilitated by consulting Fig 18 The disease affects the *spinal ganglia* and the *dorsal roots which lie between the ganglia and the cord* It frequently spreads to the *rami communicantes* (which connect the spinal cord and the autonomic nervous system). The disease ascends from these tissues and causes a selective *degeneration in the posterior white columns of the cord* (the columns of Goll and Burdach) Only very rarely are other parts of the spinal cord involved The degenerative process often extends to certain lower brain centers, where the curious selectivity of the disease is again shown by the fact that it almost always attacks the *nuclei of the optic nerve and of the nerves which supply the ocular muscles*, and only infrequently the nuclei of other cranial nerves

Although the only cause of tabes is syphilis, only a small percentage of syphilitics ever shows tabetic symptoms It is not known why some syphilitics develop tabes while the majority does not Tabes usually occurs late in the course of syphilis, from 8 to 15 years after the initial infection

Symptoms. The symptoms of tabes are clearly correlated with the disturbed condition of the specific structures involved These symptoms may be divided into four general groups

1 *Pain* is almost always a prominent symptom, because of the sensory disturbances which result from the infection of the spinal ganglia and dorsal roots The site of the pain depends directly on the particular ganglia and roots involved If the disease is at the lower cervical and thoracic[1] levels, the patient reports pains in the arms If the lumbar and sacral roots[2] are affected, the pain is localized in the legs The pains are sometimes acute but transitory

[1] The *cervical* section of the spinal cord is the section which lies closest to the head It gives rise to spinal nerves 1 to 8 inclusive The *thoracic* section lies between the cervical and the lumbar sections, it gives rise to spinal nerves 9 to 20 inclusive

[2] The *lumbar* section of the spinal cord which lies immediately below the thoracic section gives rise to spinal nerves 21 to 25 inclusive The *sacral* roots are the roots of the spinal nerves 26 to 30 inclusive The sacral nerves, together with the 31st (the *coccygeal* nerve), emerge from the lowest part of the spinal cord

and are described as "shooting" pains, at other times, they are both intense and lasting "Girdle" pains which encircle the body at one or another level are common The location of the girdle always corresponds to the distribution at the skin surface of the spinal nerves the dorsal ganglia of which are diseased When, as frequently happens, the disease spreads to the rami communicantes, acute visceral pains, known as "crises," occur These are abrupt in their onset, and after lasting from a few hours to a few weeks, disappear suddenly, only to recur again and again Depending upon the level at which the rami communicantes are involved, the crisis may be localized in the rectum, bladder, or sexual organs (if the lowest roots are affected), in the larynx, pharynx, salivary glands, or tear glands (if the disease process extends to certain of the cranial nerves), but most frequently, the site of the crisis is the stomach, and the patient suffers not only from pain, but also from retching, vomiting, inability to retain food, and consequent emaciation

2 *Ocular disturbances* result from the involvement of the motor cranial nerves (which control eye movements and the pupillary reflex to light) and of the optic nerve (which mediates vision) Thus, a lesion in the fibers underlying the pupillary light reflex produces the *Argyll Robertson sign*, in which the *pupils* do not react to changes in light, but do respond in convergence[1] and in accommodation[2] In addition, the pupils are frequently contracted, irregular in outline, and unequal in size Involvement of the nerves which control the movements of the eyeball itself results in the *paralysis of some or all of the six extraocular muscles*, so that the eyes can be moved only in certain directions or not at all These paralyses usually are unequal in the two eyes The patient often reports *diplopia* (seeing single objects double) The ocular paralyses may also cause a form of *strabismus* ("cross eyes") and *ptosis* (drooping eyelid) When the disease attacks the optic nerve, as it usually does, there ensues a gradual *impairment of vision* (the loss being first for colors, later for brightness), a decrease in the size of the visual field, and ultimately, blindness in most cases

3 A *disturbance of the sense of position, movement, and vibration*

[1] *Convergence* is the process by which the eyeballs are automatically turned in toward the nose in adjusting for the seeing of near objects

[2] *Accommodation* refers to automatic adjustments in the shape of the lens for the seeing of objects at different distances

results from the destruction of the posterior columns (the columns of Goll and Burdach) This symptom, which is invariably found in tabetics, is due to the fact that the posterior columns contain the ascending tracts which convey impulses from receptors in muscles, tendons, and joints to higher centers in the brain If the patient's eyes are closed, and a limb is raised or lowered or moved sideways by the physician, the patient will not be able to report the direction of the movement If a tuning fork is held to the surface of the skin, he will be unable to detect its vibration A disturbance of reflexes is shown by a *reduction or loss of knee-jerks and ankle-jerks*, reactions which depend for their occurrence on the presence of intact pathways through the dorsal roots and the posterior columns of the cord

4 Because of the fact that the patient is partially or completely insensitive to changes in position and movement, *ataxia* develops Ataxia is a loss of the power to coordinate voluntary movements It may arise from any one of several causes, but in tabes it is due to the failure of impulses from muscles, tendons, and joints to reach the brain centers for coordination The ataxia is almost always first manifested only in the lower extremities, the upper limbs being affected later There is marked insecurity in walking, and a flinging about or flopping of the legs and feet The feet are advanced irregularly and stiffly The toe is turned upward and when the foot descends, it does so with a thump upon the heel Moreover, the foot is raised abnormally high at the end of each step The tabetic patient is less ataxic when his eyes are open, which is the reason why he closely watches his feet and the ground on which he walks The tabetic sways markedly when he is simply standing still with his eyes closed (*Romberg's sign*) In fact, all motor acts of the voluntary type are jerky, uncoordinated, and lacking in precision The ataxic gait which results from tabes is shown in the photographs of Fig 22

Symptoms of *trophic disorders* are often present These arise from disturbances of the sympathetic division of the autonomic nervous system, by way of the syphilitic invasion of the rami communicantes Of the trophic disorders in tabes, the most frequently encountered are afflictions of the joints (often resulting in deformities), as well as "spontaneous" fractures and perforating ulcers (especially of the soles of the feet)

"Mental symptoms, aside from the general mental change in a person who is afflicted with a chronic, progressive, and ultimately incapacitating and hopeless disease, do not occur in tabes ..."[1]
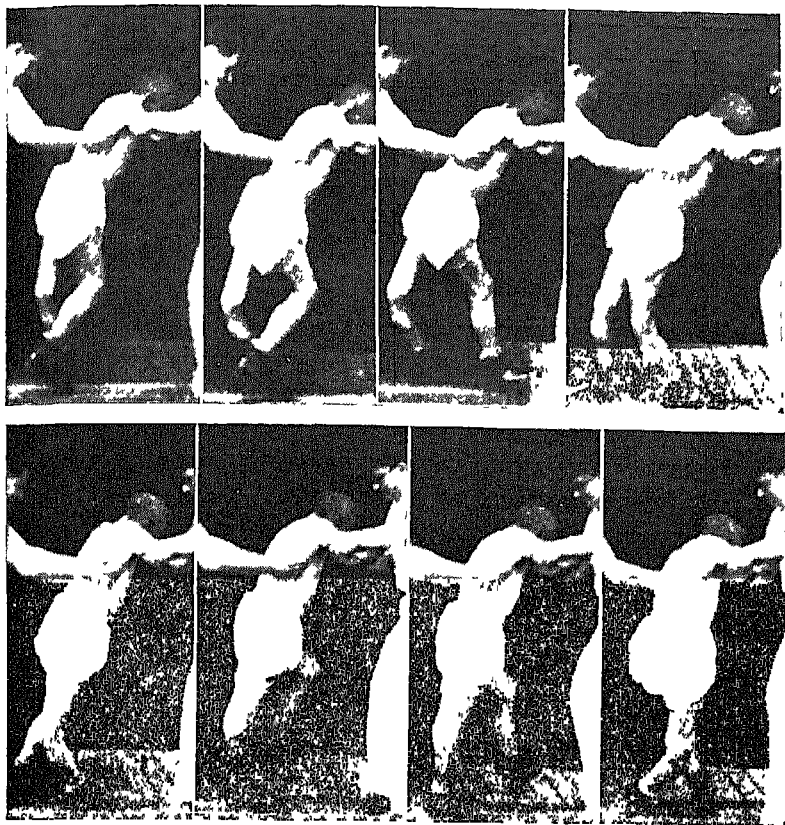
Fig 22 Locomotion in Tabes Dorsalis

The patient shows the tabetic gait, with severe ataxia and marked muscular weakness (*Reproduced from photographs in the possession of Ernst Herz, M D, by courtesy of Dr Herz and of the King's Crown Press, publishers of Ernst Herz, M D, and Tracy J Putnam, M D*, Motor Disorders in Nervous Diseases, *1946*)

but constitute a prominent feature of paresis, also a syphilitic disease of the nervous system, which is described below

Prognosis and Treatment Tabes is a gradually progressive disease With the passage of years, the patient typically becomes increasingly incapacitated by the ataxia and by the pains, especially if these in-

[1] Wechsler, *op cit*, p 460

volve "crises." He often has recourse to the use of one or two canes, in time is limited to "locomotion" by wheelchair, and ultimately becomes bedridden

There is no known cure for tabes In the attempt to prevent the development of tabetic symptoms in syphilitic patients, it is customary to continue the antisyphilitic treatment until the blood Wassermann test for syphilis becomes negative and until examination of the spinal fluid shows no evidence of invasion of the nervous system by the *Treponema pallidum*, the syphilis spirochete The likelihood of arresting the progress of the disease by the use of the usual antisyphilitic drugs (*bismuth*, *mercury*, or the *arsenicals*) is greater early in its course than when the disease has done extensive and irreparable damage However, cases in which there is atrophy of the optic nerve often respond poorly to these drugs, in fact, in many cases acceleration of the atrophy and a more rapid advent of total blindness have been attributed to such treatment Recently, *fever treatment*[1] has been used in tabes as it has in general paresis, but the success with the former condition has not been striking

In the treatment of the tabetic pains, the usual analgesic drugs are used Since these only control the symptom and do not cure the underlying cause, they must be administered often But for the gastric crises, there are no known drugs or treatments which yield even appreciable temporary relief

Nor can the ataxic process be reversed Once the neurones have been destroyed, they cannot be regenerated and therefore there is no structural basis for a restoration of function It is true that there are cases of even bedridden tabetics who have learned to walk again as a result of special retraining methods The beneficial effects achieved by such methods depend not only on the physician's skill, but in large measure on the patient's learning to conquer fear and shame, to use more efficiently whatever intact nerve fibers have remained, and in the performance of his movements to rely more than do normal individuals upon stimuli which are not kinesthetic in nature (*e g*, visual stimuli)

GENERAL PARESIS

Pathology. General paresis is a disease of the nervous system which characteristically progresses gradually, if not treated it is

[1] See pp 212–213

usually fatal, although its course is often marked by periods of arrest of the symptoms or even of improvement The cause is the same as that of tabes dorsalis, that is, the invasion of the nervous system by the syphilitic spirochete (*Treponema pallidum*) However, in tabes the infection is confined in the main to the spinal cord, whereas the brain, primarily the cerebrum, is the focus of the disease in paresis.[1] The disease usually appears between the ages of thirty and fifty, but is far from unknown at earlier and later ages

The essential features of the disease consist (1) of *inflammation of the meninges, especially those of the brain* (see Fig 21), and (2) of a *diffuse inflammation and degeneration, mainly of the brain, but to some extent of the cord and sometimes of certain of the cranial nerves* Paresis involves the actual destruction of nervous tissue by the syphilitic organism and the poisoning of nervous tissue by the by-products of the infection The most characteristic feature is an atrophy of the convolutions of the brain, especially in the frontal and parietal lobes, because of the damage to the cortex and to the nerve fibers In some areas of the cortex the gray matter becomes extremely poor in cells On the surface of the cortex there is a marked increase in the number of supporting (nonnervous) cells, forming a dense fiber meshwork

The meninges of the brain—the dura mater, the pia mater, and the arachnoid—are always affected, all three of them showing thickening The dura becomes adherent to the cranial bones (*i e* , the skull), and the pia and the arachnoid to the cerebral surface (*i e* , to the cortex)

Degenerative changes are also found in lower brain areas, such as the cerebellum and the nuclei of certain cranial nerves The cranial nerve nuclei which are most frequently attacked by the syphilitic process are the cells of origin of the fibers which mediate vision and hearing and which control movements of the eye muscles

The spinal cord is frequently involved by the infection of the posterior white columns (the columns of Goll and Burdach) and of the lateral corticospinal tract (see Fig 19)

A common effect is *hydrocephalus*, a condition in which the quantity of cerebrospinal fluid is excessive, either because of a too rapid accumulation of the fluid or its failure to circulate at the normal rate

When the paretic neural pathology includes degenerative changes

[1] As was pointed out in the discussion of *tabes dorsalis*, it is not known why only about 5 per cent of syphilitics develop syphilis of the nervous tissue

which also occur in tabes dorsalis, *i e*, involvement of the posterior white columns and of the optic nerves, the disease is known as "taboparesis"

Other pathological signs exist, but they are not found as regularly as are those that have been described

Symptoms As a result of the diversified and widespread character of the pathologic processes in the nervous system, the symptoms are numerous and varied

Certain of the symptoms are important primarily as clinical signs of brain damage Among these are *ocular disturbances*, involving pupillary disorders and paralyses of the extraocular muscles, very similar to those seen in tabes dorsalis and deriving from the affliction of the same cranial nerves as in tabes However, the optic nerve is less frequently involved in paresis and therefore optic atrophy and blindness are less common than in tabes *Convulsive or paralytic attacks*, though not invariable, are very common, especially late in the course of the disease The convulsion may occur in any part of the body, but usually it is generalized It may last from a few minutes to a half hour, may be mild or severe, may occur as a single episode or be repeated again and again at short intervals Sometimes the attack takes the form of a paralysis, either partial or complete, which usually disappears within a few hours or days, late in the disease, however, these paralytic attacks are followed by permanent impairment of movement [1] *Abnormality in speech and writing* is very characteristic of paresis Speech tends to become tremulous, slurred, marked by elisions and stammering Writing, too, usually has a tremulous quality and shows omission, doubling, and transposition of letters Certain features characteristic of tabetic handwriting are shown in Fig 23 Thus, as a result of the irreparable damage to the neural structures underlying the language functions, the symbolic skills of the paretic patient are gravely impaired and his processes of communication and of organized thought disrupted If the spinal cord (including the posterior columns), as well as the brain, is extensively involved, the symptoms include the disappearance of the ankle and knee reflexes, the Romberg sign and ataxia, bladder disturbances, and other symptoms of tabes

[1] These gross muscular disorders have been ascribed to circulatory disturbances in the brain or to episodic invasion of the brain by increased "showers" of spirochetes

From the viewpoint of psychological adjustment, general paresis is revealed as a *psychosis*, involving progressive mental deterioration (*dementia*). This deterioration is shown in the progressive impairment of intelligence, memory, moral judgment, and emotional control. These symptoms, as they develop, reflect the progressive involvement of various regions of the brain. Frequently the course of the disease is marked by *remissions* (transient diminutions or abatements of the
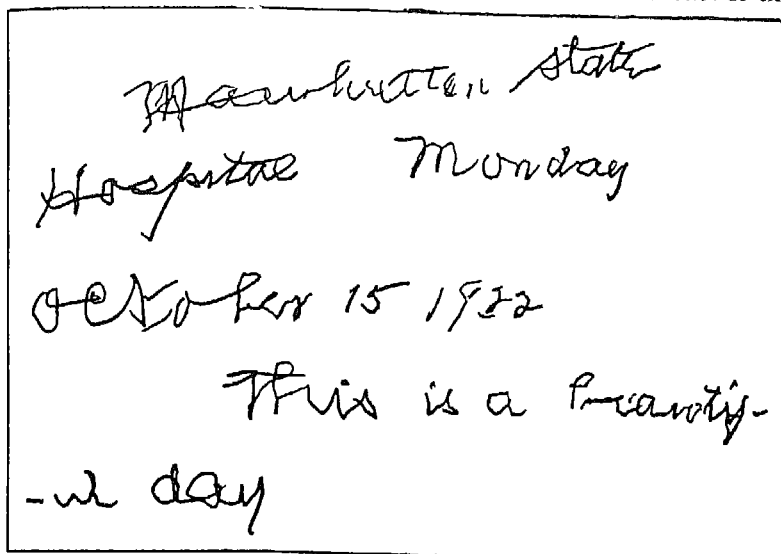
FIG. 23. Paretic Script

Disturbance of coordination is especially plain in the M and in the word "beautiful," the former showing this disturbance by the interruptions in the lines, and by the numerous but vain efforts to continue the strokes.

symptoms), which are thought to be due to a temporary subsiding of the pathologic processes that results from a physiological defensive reaction to the syphilitic invasion.[1]

The diagnosis of general paresis is based less on the nature of the individual symptoms, which often occur in other organic psychoses, than on their manner of onset, coupled with the typical signs of motor disturbance and the characteristic blood and spinal fluid changes.

As a rule, the first overt signs of the disease are *personality changes* or changes in general behavior. The individual may show lack of

[1] Wechsler, *op. cit.*, p. 445.

power of concentration, easy fatigability, and irritability Sometimes he becomes overanxious and depressed and suffers from insomnia Soon, however, symptoms of greater gravity appear The person begins to avoid responsibility, becomes indifferent to all his affairs (business, personal, and social), and careless in his dress and manners He may even commit moral delinquencies, such as theft, sexual excesses, or drunkenness, which would have been entirely foreign to his nature before the onset of the disease *General intelligence shows degeneration* and there is always *impairment of memory*, especially for recent events The patient cannot remember even simple things told to him a short while ago, cannot recall having met recent acquaintances, forgets appointments and where he has left personal belongings One result of the memory impairment is that he often repeats himself, relating a story to the same person over and over again in the same detail The patient becomes easily confused in a new environment Sometimes marked changes in temperament occur, so that a previously even-tempered man becomes irritable and even violent, and a formerly jovial man becomes sullen, sulky and apathetic Also, in general, the paretic shows a degree of instability and unpredictability alien to his pre-disease behavior

As the disease progresses, different types of personality aberration may be shown In the *grandiose or expansive type*, there are usually early signs of excitement or even manic outbreaks But soon delusions of grandeur, coupled with euphoria (feelings of well-being which are usually unfounded and exaggerated), dominate the scene The patient "never felt so well in his life", he has the physical power of Hercules, he has millions of dollars, is an emperor, or has 10,000 children At the same time the "expansive" paretic is often very irritable and is incoherent in the expression of his fantastic ideas The *depressed type* from the first tends to be overanxious and despondent He often expresses feelings of inadequacy and self-accusatory ideas (*e g*, believing himself guilty of unpardonable sins for which he will be mercilessly punished) In time the depression deepens and the patient is obsessed with hypochondriacal delusions (*e g* his heart has been filled with water, his brain has been removed, there is an obstruction which prevents him from ever moving his bowels) Profoundly melancholic, the patient may attempt suicide The *demented type* is characterized by gradual mental deterioration, apathy, loss of

memory (especially for recent events), neglect of personal hygiene, and personality defects. The patient often has mild grandiose ideas and other simple delusions. Finally, a *simple and slowly progressive type* of general paresis has been described, which is for years characterized by only a few mild behavioral disorders and physical symptoms of a pathological nature. The diagnosis of these cases is based primarily on the findings of tests of the blood and spinal fluid.

Without question, many of the behavioral symptoms of paresis (*e.g.*, loss of memory, disturbance in language) arise as a direct result of brain damage due to the inroads of the spirochete. However, it is very likely that some of the symptoms, especially those reflecting emotional and general personality disturbances, may be explicable, in part at least, by the patient's reaction to the effects of the organic damage, *i.e.*, to his illness. It may be the confusion and insecurity engendered by the patient's decreasing general competence that cause his depressions, the delusions of grandeur may result from an unconscious attempt by the patient to conceal from himself the knowledge that his personality is disintegrating. If it is true that the behavioral symptoms in paresis are partly a result of the patient's psychological reaction to the ravages of the disease, it is not surprising that individual paretics should show wide differences in the nature of their personality disorganization. As Wechsler says, "The psychotic manifestations can sometimes be correlated with the previous personality and character make-up of the individual. . . ."[1] Thus an excitable person may develop the expansive type of personality deviation, a phlegmatic individual the depressed type, etc. The same view is expressed by another neurologist who holds that the behavior pathology which a paretic develops is determined "by his premorbid personality structure and its underlying emotional trends and conflicts."[2]

Prognosis and Treatment. In untreated cases the prognosis of general paresis is very grave. Although the rate at which the disease process develops may vary from slow and insidious to very rapid, and although in some cases remissions and even apparent "spontaneous" recoveries enduring from two to six months may occur, ultimately all the symptoms become aggravated, mental and physical deterioration

[1] Wechsler, *op. cit.*, p. 447.
[2] Grinker, R. *Neurology*, 3rd ed. Springfield, Ill.: Charles C Thomas, 1943, p. 905.

increases, speech becomes progressively more difficult and more incomprehensible, until finally the patient is bedridden, a completely demented, helpless, vegetative organism Untreated, the disease is fatal, usually within two or three years, in almost 100 per cent of the cases

Chances for recovery in treated cases vary with the nature of the treatment and with the time at which the treatment is instituted Before discussing methods of therapy, however, it should be pointed out that it is more correct to speak, in most cases, of the arrest of paresis rather than of recovery or cure, since, as we have said, nervous tissue that has been destroyed cannot be restored

Various methods have been used in the treatment of paresis, all of which have as their aim the elimination of the infectious process which underlies the physical and psychotic symptoms However, the method in most common use today involves *fever therapy*, often combined with penicillin,[1] followed by antisyphilitic treatment with arsenic compounds and bismuth The accepted mode of fever therapy in paresis at the present time is by the inoculation of the patient with the malaria organism, so that he develops malaria with its alternating high fevers and chills This treatment is based on the knowledge that the human constitution can recover from internal temperatures (*i e*, of 104° to 106°F) which are fatal to the *Treponema pallidum* After the patient has had 10 to 15 chills, antimalarial treatment with quinine is begun[2] Following recovery from the malaria, a standard antisyphilitic treatment is given, usually involving tryparsamide (an arsenic compound) alternating with bismuth The administration

[1] During the fever therapy penicillin is often administered at 3 hr intervals for a period of 4 weeks Authorities state that experience has not as yet been sufficient to permit a full evaluation of the effectiveness of penicillin in the treatment of paresis

[2] There are, of course, certain dangers in the use of this form of fever therapy, because of the hazards of malaria itself The treatment is most effective when given to young and healthy patients in the early stages of paresis For aged patients and for those in advanced stages who have undergone serious physical deterioration, the treatment may actually hasten death

In certain cases "artificial" fever is induced, not by malaria, but by such means as wrapping the patient in an electrically heated blanket, placing him in a short wave radio field, or surrounding him with hot humid air These methods have the obvious advantage that the physician can control the degree of fever and its duration with precision A number of authorities, however agree that generally the malarial method gives better results, perhaps certain biochemical changes resulting from the malarial infection are valuable in neutralizing toxic products of the syphilitic infection

of these drugs in accordance with the established regimen is necessary after the fever therapy, since in many cases improvement in symptoms following the malarial infection is not accompanied by a change from positive to negative results in the blood and spinal fluid tests for syphilis This combined fever and pharmaceutical treatment has resulted in arrest of the disease in about 50 per cent of the cases, with "remissions amounting to permanent cures in about 30 per cent of cases "[1]

Psychotherapeutic methods have also been used to aid in the readjustment of medically treated paretic patients

Discussion

Of the whole array of diseases of the nervous system, only a very few have been singled out for description here These few have, of necessity, been presented briefly and incompletely But even this short account should suffice to show how greatly human behavior depends upon sound structural and functional conditions in the nervous system and, further, how specifically localized disorders in the nervous system produce specific abnormalities of behavior The ataxic gait which is a symptom of tabes dorsalis can be directly ascribed to injury of the fibers which ascend to the brain in the posterior white columns The limp paralysis of infantile spinal paralysis results from the deterioration of the ventral-horn cells of the gray matter of the cord In syringomyelia the loss of pain and temperature sensitivity in restricted areas of the skin is caused by the destruction of the anterior commissures which lie near the central canal of the spinal cord A progressive deterioration of personality and of thinking functions parallels the progressive destruction of cerebral cortex in paresis The foregoing pages furnish many other examples of the correlation between specifically localized disturbances in the nervous system and specific types of behavior disorder

However, certain cautions are necessary with respect to our interpretation of these neurological findings It must be pointed out that the close relationship between specific neural pathology and specific behavior abnormality may not be found when the disease or injury is principally confined to the cerebrum, or when the behavior abnormalities are disturbances of such "higher processes" as learning, memory, and thinking Each particular spinal center has a function

[1] Wechsler, *op cit*, p 452

which is specific and relatively invariable. It follows that if this particular center is injured, a specific impairment of behavior will result. But for the most part no such specific functions can be definitely assigned to the various areas of the cerebrum. Hence, damage to one particular group of neurones in a particular region of the cerebrum may not result in one and the same variety of behavior disturbance in all individuals. In other words, there is no exact correspondence between symptoms, on the one hand, and the extent and location of certain types of cerebral injury, on the other. Furthermore, injury or disease of the cerebrum usually has a general rather than a narrowly specific effect on behavior and commonly produces profound disturbances of the most complex psychological processes, as well as of simple sensory and motor functions. An example of the evidence on which these conclusions are based is to be found in the description of general paresis in this chapter.

Another point which the reader should bear in mind is that there are no known neurological bases for many of the most common "mental" disorders. This statement does not mean that such disorders occur in the absence of any disturbance of neural functions. What is meant is, rather, that many "mental" disorders apparently do not arise as a result of any actual damage to the nervous system from tumors, hemorrhages, concussions, wounds, bacterial infections, or any similar cause. The loss of kinesthetic sensitivity in locomotor ataxia is clearly traceable to damage done by the syphilis spirochete to certain particular tracts of the spinal cord. But nail biting, or stuttering, or a fear of cats, or a feeling of inferiority, or an inability to control one's temper can only very rarely be attributed to actual damage of tissue anywhere in the nervous system. As a rule, there is no evidence in such cases that the nervous system is diseased or infected or in any way structurally damaged, although in some grave disorders, such as schizophrenia, detrimental biochemical conditions may be basically involved.[1] Hence, the treatment for such conditions usually consists of attempts to alter the undesirable behavior by purely psychological methods (*e.g.*, reconditioning), rather than by the employment of surgical or other medical remedies. Certain of these methods are described in Chap. XIX of this book.

[1] Hoskins, R. G. *The Biology of Schizophrenia.* New York, Norton, 1946.

CHAPTER XII

THE ELECTROPHYSIOLOGY OF THE NERVOUS SYSTEM

INTRODUCTION

Readers of newspapers and magazines are becoming somewhat used to the periodic appearance of articles headlined "Recently perfected device records man's thoughts electrically" Such reports leave one with the impression that the precise neural correlates of "thought" have been discovered, that means to record them have been devised, and that in order to find out what a person is thinking a skilled technician need only start his apparatus and analyze the resulting graphic records of "brain waves"

But psychology and neurology have not advanced quite so far as such articles suggest Our knowledge of the modes of action of the nervous system is still very far from being complete Just how the brain functions in thinking remains largely unknown And although it is possible to record "brain waves," as the experiments reported in this chapter show, the "waves" that have been recorded most successfully do not seem likely to have a direct relation to thought processes

Yet if the investigations of "brain waves" have not yielded the dramatic results claimed for them by some popular science writers, they already have added considerably to our understanding of a number of psychological phenomena and they offer hope of illuminating the still mysterious relationship between neural activity and overt behavior The present chapter deals with a few recent studies which have been selected to indicate the number and variety of psychological problems which controlled observations of these neuroelectrical waves may help to solve

One of the basic discoveries in the field of neurophysiology was Helmholtz's proof that nerve impulses travel at measurable speeds, far below the speed of electromagnetic impulses Less than one hundred years ago Johannes Muller, the most eminent physiologist of his day, taught that the *velocity of conduction of the neural impulse* could never

be determined precisely, since its rate of propagation must approach that of light (about 186,000 miles per second). But by 1850 Helmholtz had shown by simple means that in the frog's sciatic nerve the velocity of propagation is only 28 m. (approximately 92 ft.) per second, and it was soon demonstrated that the speed of conduction is but 120 m. (about 394 ft.) per second in the most rapidly conducting medullated nerve fibers of the human nervous system. These and later investigations did much to remove the problem of the neural impulse from the realm of mysticism and to show that the phenomenon can be measured and described in terms of physicochemical principles. At the present time, there is considerable evidence in support of the view that the neural impulse may best be described as a wave of electrochemical change.

In the study of the electrical characteristics of neural functioning, the "action-potential" technique has been of very great service. Many years ago, it was discovered that if electrodes are placed in contact with active nerves, the changes in electrical potential involved in neural transmission can be made to bring about deflections in a sensitive galvanometer.[1] Recently several investigators have employed vacuum tubes to amplify the minute "action potentials," and elaborate oscillographs have been devised for graphic or photographic recording of the electrical changes. (The essential features of an apparatus for recording action potentials are shown in Fig. 24. In this particular circuit, the cathode-ray oscillograph replaces the galvanometer.) Such amplification and recording have made possible the study of numerous aspects of neural transmission which previously defied investigation. More accurate determinations have been made of the velocity of conduction in different fiber groups. For example it has been shown that the fibers of relatively small diameter which conduct afferent impulses from "pain" receptors transmit their impulses at lower speeds than do those larger fibers which transmit

[1] A galvanometer is an instrument used to detect and to measure very weak electrical currents. While a nerve fiber is conducting an impulse, the surface of the fiber in the region where the impulse is passing at any given instant is at an electrical potential different from that of the surface in any other region of the fiber. Thus, waves of change of electrical potential sweep along the nerve fiber with the impulse, and it is these changes of potential that set up the weak currents which account for the deflections of the galvanometer. The currents are called "action currents," and the potentials causing the currents "action potentials."

impulses from cutaneous pressure and temperature receptors The rhythms of discharge of different groups of fibers can now be studied and compared The well-known "all-or-none" principle of conduction[1] which Adrian originally demonstrated without the aid of the action-potential technique has now been verified through action potential observations

These action-potential observations also indicate that when impulses are aroused through the stimulation of receptor mechanisms, the
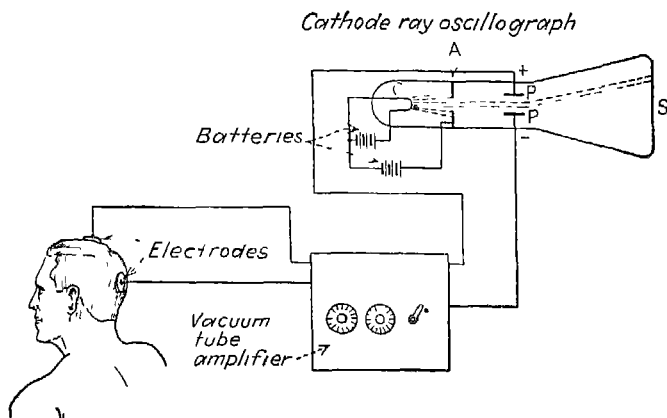
Fig 24 Diagram of One Type of Circuit Used for Recording Cerebral Action Potentials

In the cathode ray oscillograph, C is the cathode, from which electrons are emitted A beam of electrons passes through an opening in the anode, A, and falls on screen S When changes in the electrical potential of plates $P - P$ occur the beam of electrons is deflected and when a succession of changes occurs, as in the case of brain rhythms curves are traced on the screen A camera, mounted to face this screen will take permanent records of the waves (still or motion picture) Some investigators use a sensitive galvanometer instead of the cathode ray oscillograph in which case records are made photographically by having the galvanometer mirror reflect a beam of light upon a moving strip of photographic film or paper

frequency of discharge (number of impulses conducted per second) along the afferent nerve fibers increases when the intensity of the stimulus is increased (In a certain nerve in the frog the frequency of discharge has been found to vary from 5 to 100 impulses per second, depending upon the intensity of the stimulus) The fact that the

[1] The nerve fiber, like a shotgun, operates on the "all-or-none" principle If a sufficient force is applied to the trigger of the gun, the firing pin is released and the gun discharges completely It is impossible to increase the magnitude of the discharge by increasing the force exerted upon the trigger Likewise the nerve fiber does not transmit larger or more "vigorous" impulses in response to more intense stimuli Each impulse is the same regardless of stimulus intensity provided the latter exceeds the threshold value

frequency of discharge is a function of the intensity of stimulation has come to be known as the "Adrian principle," since Adrian was the first to demonstrate this relationship[1]

Much of the important recent work on the electrophysiology of the nervous system has involved the recording of action potentials from the cerebral cortex itself The enormous complexity of cortical action and our ignorance of the precise mechanisms which control cortical functioning perhaps make it difficult for us to appreciate the full significance of these action-potential records Nevertheless, various types of brain-wave patterns recorded and the variations which occur in these patterns under changing conditions are definitely worthy of our attention, even though we are not yet in a position to understand them fully

Of course it is not possible to apply electrodes directly to the human cerebrum save in cases where severe injury to the skull has exposed the brain surface Some years ago, however, Berger,[2] a German physiologist, discovered that with the use of appropriate amplifiers cerebral potential waves might be recorded by placing the electrodes upon the surface of the scalp This record constitutes what is called an "electroencephalogram," often abbreviated E E G Berger discovered two distinct types of brain-wave rhythms, and during the past 20 years other investigators have observed and recorded many other important kinds A classification and description of the principal types follow, together with illustrations of them in Fig 25

TYPES OF BRAIN WAVE[3]

Type I. Berger's Alpha Waves. These are regular rhythms with definite frequencies, usually between 9 and 11 cycles per second, though some investigators report a range of 8 to 13 cycles in the normal adult They appear in most adults, vary in amplitude (voltage change), and

[1] For summaries of many important neurophysiological studies, including some of Adrian's more important investigations, and a partial bibliography on the subject, see Evans, C L *Recent Advances in Physiology*, 4th ed, Chap IX London, Churchill, 1930, and Adrian, E D *The Physiological Background of Perception* New York, Oxford, 1947

[2] Berger, H Über das Elektrenkephalogramm des Menschen *Archiv fur Psychiatrie und Nervenkrankheiten*, 1929, vol 87, pp 527–570

[3] The description of all the types, except gamma, delta, and the "spike" variety, is taken from Loomis, A L, E N Harvey, and G G Hobart, Electrical Potentials of the Human Brain *Journal of Experimental Psychology*, 1926, vol 19, pp 249–279 (The original numerical designations have been altered)

appear and disappear readily according to the subject's "mental" and emotional activity Berger found that alpha waves may be observed in a normal adult, who is seated comfortably and has his eyes closed, if one electrode is placed in contact with the scalp in the occipital region and the other at some other point of the scalp surface
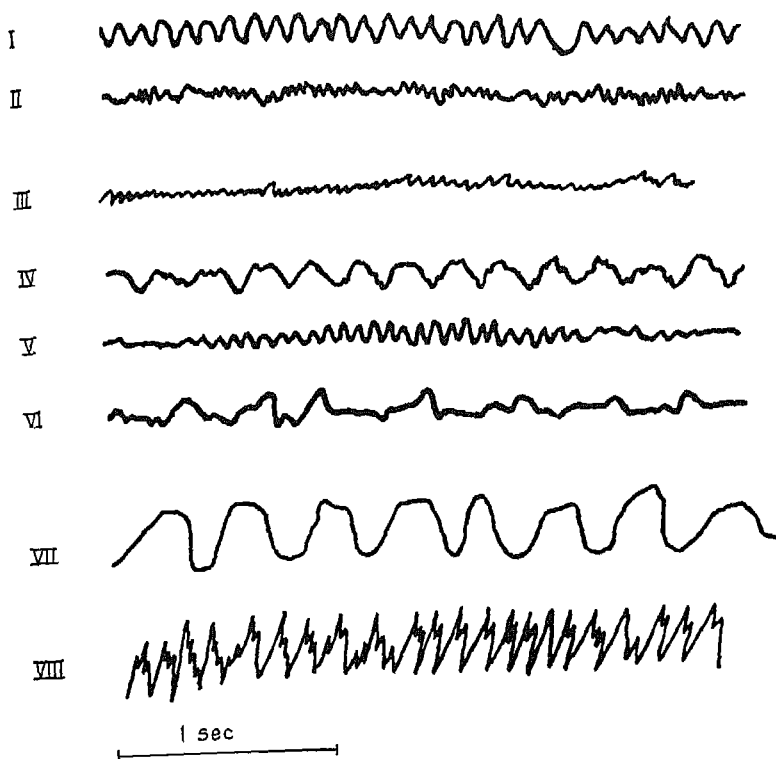
Fig 25 Graphic Records of the Eight Types of Cerebral Action-Potential Waves Described in the Text

I, alpha, II, beta, III, gamma, IV, saw-tooth, V, spindles, VI, large "random waves", VII, delta, VIII spikes As the length of the line labeled "1 sec" indicates, each of the above records covers a period of 3 sec

(the exact location of the second electrode being immaterial if it covers a sufficient area) However, if the subject opens his eyes to look at an object, or starts to read, these alpha waves disappear Many investigators have verified these observations The alpha waves have the greatest amplitude, *i e*, the greatest voltage change, of any

of the several types of potentials which have been recorded from the surface of the scalps of normal awake subjects, and they tend to be strongest in the occipital regions They first appear at the age of three to four months, at frequencies as low as 3 or 4 cycles per second, the frequency increases as the child develops, until it finally reaches the level of 9 to 11 per second which is characteristic of the adult

Type II Berger's Beta Waves. These are very rapid variations in potential, averaging from 25 to 35 cycles per second They seem to represent a secondary series of waves which are often superimposed upon the alpha waves, but they may continue after the alpha rhythm has dropped out Their amplitude is only about one-fourth that of the alpha waves Beta waves predominate in the records of some subjects in whom the alpha waves are weak They persist during visual stimulation when there are no alpha waves, but they are often diminished by stimuli which startle the subject These waves may be closely related to activities of nerve cells in the anterior part of the cortex, since they are more prominent in the records when leads are taken from the frontal lobes

Type III. Gamma Waves Waves for which this name has been suggested are even more rapid than beta waves They occur with a frequency of 35 to 60 per second, and are more often observed in the occipital region than are the slower beta waves

Type IV Saw-tooth. These are large and slow variations in electrical potential occurring at a frequency of about 4 to 7 cycles per second, but without a very regular rhythm They are common in young children

Type V Spindles These are waves with regular frequencies of from 12 to 15 cycles per second They come in trains, increasing in amplitude up to the middle of the train and decreasing toward the end of it—a peculiarity which gives the whole train a spindlelike appearance on the graphic record The spindle waves are observed only while the subject is sleeping

Type VI. Large "Random" Waves. These waves recur irregularly at frequencies from 0 5 to 5 per second, and are characteristic of sound sleep

Type VII Delta Waves These are large, slow waves having a frequency range of 0 5 or less to 5 or 6 per second They have been observed in persons with epileptic tendencies, in other abnormal

brain conditions, and in deep sleep They are usually of the "flat-top" or "dome" variety, and they sometimes have smaller waves of higher frequency superimposed upon them

Type VIII. Spikes. These are extremely pointed waves often observed during epileptic seizures During a *grand mal*[1] attack they may occur with increasing frequency, sometimes reaching a maximum of 25 per second at the height of the attack This type of wave is shown in both Fig 25 and Fig 26 A typical *petit mal*[1] record shows alternate spikes and flat-top delta waves at a rate of about 3 per second, as shown in Fig 26

As the above classification shows, a considerable variety of different wave rhythms has been observed in the human cortex, and furthermore, the kind of wave which is recorded at a given time is dependent upon many different factors, such as the age of the subject, whether the subject is being stimulated visually, whether he is asleep or awake, and so on

During the past two decades, many investigations have been conducted with the aim of discovering the nature of the predominant brain rhythms under different conditions, and the effect of varying these conditions (*e g*, modes of stimulation) upon the wave forms One of the best examples of such studies is the experiment of Loomis, Harvey, and Hobart already referred to

I Action Potentials of the Human Brain[2]

PURPOSE

The purpose of the experiment of Loomis and his associates was to record and compare action potentials from the brain under different conditions of stimulation and in subjects of different ages

METHOD

The subjects of the experiment were 29 individuals who ranged in age from seventeen days to seventy-four years The action potential records were obtained by means of the technique described above The various specific conditions of stimulation which were employed are stated in the summary of results which follows Records were

[1] See Part II of this chapter for a brief description of epilepsy, the nature of ***grand mal*** and *petit mal* attacks, etc

[2] Adapted from Loomis, Harvey, and Hobart, *op cit*

obtained from each subject for a period of at least 2 hours, and one subject was studied continuously for a total period of 50 hours

RESULTS

Alpha Waves: Brain Waves during Sleep. The findings of Loomis and his associates verified the conclusions of previous investigators that the *alpha rhythms* (Type I waves) appear in normal subjects who are at rest with closed eyes, and that they disappear when the subject opens his eyes to view an object, to read, or to react attentively in any way It was further observed that, when the subject retired for sleep, the alpha waves continued as long as he was relaxing quietly, but that as he became drowsy they became less frequent, and were gradually replaced by the *random potentials* (Type VI), which are characteristic of sound sleep

When subjects awakened during the night trains of alpha waves usually appeared at once and then changed gradually to the random type as deep sleep came on again

In a number of sleeping subjects, trains of waves of the *spindle type* (Type V) appeared Their frequency was from 13 to 15 cycles per second, and the individual spindles lasted from ½ to 1 second These spindles were recorded only during sleep and for the most part in adult subjects Children and young persons in very deep sleep showed the *random* (Type VI) wave predominantly, with only occasional spindles

The Effect upon Brain Waves of Auditory Stimulation during Sleep Previous investigators had emphasized the fact that the *alpha waves* (Type I), which appear in a person at rest with his eyes closed, disappear when an object is viewed or when attention is concentrated upon any stimulus Loomis and his coworkers observed that the alpha waves reappeared during sleep when certain auditory stimuli were presented For example, in several subjects the rustling of paper, coughing by a person in the bedroom, closing a door at some distance from the subject, or low conversation initiated a train of alpha waves, which lasted from 5 to 8 seconds The same sounds which initiated a train of alpha waves quite regularly during sleep failed to do so when the subjects were awake Occasionally, trains of such waves appeared during sleep when there was no detectable external stimulation It is quite possible that these alpha waves were aroused by internal bodily excitation, perhaps during dreams

Brain Waves Recorded in Hypnosis. As has been said, the trains of alpha waves appear in the normal subject most regularly and continuously when he is resting quietly and comfortably with his eyes closed Opening the eyes has no effect on the waves if the room is completely dark, but if the eyes are opened in a lighted room, the waves cease If the eyes are kept open in a dark room, trains of alpha waves will disappear and reappear as a minute point of light fixated by the subject is flashed on and off This reaction occurs even when the light is so faint that it can be seen only with a thoroughly dark-adapted eye

A subject who had been hypnotized many times was tested in the normal waking state and during normal sleep Alpha waves at a frequency of 9 9 per second were recorded when the subject was awake, and the usual spindles at 12 5 per second while he was asleep After the subject was hypnotized, the *alpha waves* characteristic of the waking state continued, and neither spindles nor random waves were recorded Hence, as far as the action potentials of the brain are concerned, hypnosis for this subject was like the relaxed waking state and unlike normal sleep

To test the influence of hypnotic suggestion on the alpha waves, the subject's eyelids were fastened closed with adhesive tape Alternately, every 15 seconds, he was told, first that he could see, then that he was blind Whenever the suggestion that he could see was made, the alpha waves stopped When he was told that he could not see, the waves reappeared This happened both when there was a light in the room and when the room was in total darkness

However, suggestion alone, without hypnosis, did not have exactly the same effects

To study the effect of suggestion on individuals in the normal waking state, subjects who had never been hypnotized were tested in a totally dark room When it was suggested to a subject that he was seeing something (*e g* , a light or a face) the alpha waves disappeared, but when the room was lighted and the subject's eyes were open the experimenters were unable to start trains of alpha waves by suggesting to the subject that he was seeing nothing This finding indicates that although the alpha rhythm is influenced by suggestion in both the hypnotic state and the normal waking state, it is more susceptible to the effects of suggestion when the subject is under hypnosis

Brain Waves in Alcoholic Stupor. One subject lapsed into a stupor after he had consumed a little more than a pint of gin within a half hour, as directed by the experimenters During the stupor, he showed a marked *alpha rhythm with secondary potential waves superimposed upon it* Not only were the superimposed rhythms different from those recorded before the alcohol was taken into the body, but the frequency of the alpha waves was reduced The alpha rhythm began to disappear only after the subject had been asleep for an hour It would appear that the electrical activities of the brain in alcoholic stupor, as in hypnosis, differ from those in normal sleep

Brain Waves in Infants. Electroencephalograms were obtained from two babies every 2 weeks between the ages of seventeen and seventy-one days *Random* and *saw-tooth* waves (Types VI and IV) were recorded in the infants, but no alpha waves were observed at any time during that period (In fact, the alpha rhythm has been found to be absent in infants as old as four months) The records were very similar, whether they were made when the infants were awake or asleep [1]

II Electroencephalographic Studies of Epilepsy

Introduction

It is perhaps surprising to learn that in most mental disorders, the brain waves are not consistently different from those found in normal people Whatever may be the nature and the causes of these disorders, it appears that the brain activity is not usually disturbed in such a way as to produce an abnormal action-potential record

However, in disorders in which structural brain damage is known to be present, abnormal brain-wave records are very often reported

[1] Dr J R Smith has recorded brain waves in babies on the first day after birth The waves which he recorded seemed to originate in the motor area of the cortex (*i e*, in the pre central convolution), and were of low frequency, occurring at the rate of about 4 or 5 per second They were similar to those which have been observed in older infants during sleep *i e*, the saw-tooth waves described by Loomis, Harvey, and Hobart The occurrence of brain waves so soon after birth suggests that in all probability the rhythms have begun before birth, and that the brain is already functioning at that time Smith, J R The Electroencephalogram during Normal Infancy and Childhood I Rhythmic Activities Present in the Neonate and Their Subsequent Development *Journal of Genetic Psychology*, 1938, vol 53, pp 431-453, and II The Nature of the Growth of the Alpha Waves, *ibid*, pp 455-469

Thus, various kinds of abnormal waves are frequently observed in cases of brain tumor, neurosyphilis, and the like[1] These electroencephalographic findings may aid in the diagnosis of such disorders, and in the location of the affected areas within the brain It is believed that any kind of tissue destruction in the brain, however caused, may produce abnormal electrical potentials, usually of the *delta* type (Type VII) If the process of cell damage ceases, the electroencephalogram may return to a normal pattern, although if the destruction of nerve tissue has been sufficiently extensive, normal brain waves may never again be obtained

It so happens that the most important, and most widely publicized, studies of brain waves in abnormal individuals have been carried out on epileptics As a result of these investigations, new light has been obtained on the manner in which action-potential changes may be correlated with abnormal behavior These studies have also yielded data which are helpful in the diagnosis of epilepsy, and which have contributed materially to current theory as to the causes of this disorder

Epilepsy is a disorder characterized by recurrent seizures (or "fits") In a majority of cases these seizures are of the *grand mal* type The victim of the seizure falls to the ground and loses consciousness Violent motor convulsions then occur, lasting for 5 to 8 minutes on the average, after which the patient regains consciousness A brief period of stupor or deep sleep typically ensues Many people have seen epileptic individuals undergoing attacks of this kind on the street, in restaurants, or in other public places Another kind of seizure is the *petit mal* This variety probably would not be regarded by the layman as being epilepsy at all, since the convulsive movements may be limited to a few spasms of the face or arms, and the patient loses consciousness for only a few seconds, or does not lose consciousness at all, experiencing instead only a momentary dizziness Nevertheless, *petit mal* attacks are unquestionably epileptic in nature, and often occur in patients who have *grand mal* attacks also Other kinds of epileptic seizure also exist, but they are relatively uncommon and need not be described here

[1] See Hunt, J McV , ed *Personality and the Behavior Disorders* Vol II, Chap 33, pp 1033–1103 New York, Ronald, 1944

Gilman, R Electroencephalography Review of 1942 *Psychological Bulletin*, 1944, vol 41, pp 416–432

Electroencephalographic studies of epileptics yield several points of major interest. One finding is the striking changes in the action potentials of the brain which occur before and during a seizure. Figure 26 gives typical records for both the *grand mal* and *petit mal* types. These rhythms both show spikes (Type VIII), and the *petit*
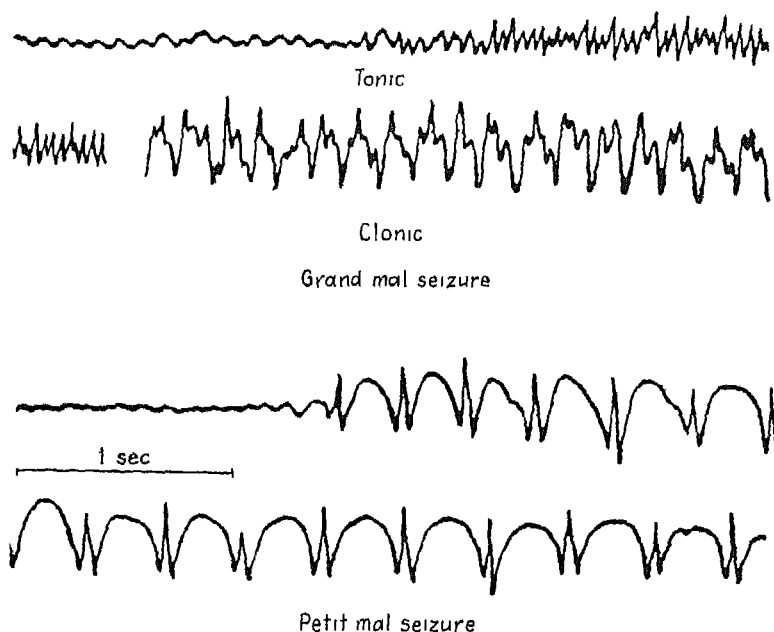
FIG. 26. Representative Electroencephalograms of Two Epileptic Patients Taken before, and during, Two Types of Seizures, *Grand Mal* and *Petit Mal*

The left of each tracing is a portion of the person's normal record. The rest of each tracing was made during a seizure. The record for the grand mal seizure shows the characteristic fast spiked waves and the increased amplitude of the waves as the seizure passes from the initial phase (called "tonic") to the complete convulsive stage (called "clonic"). The record for the petit mal seizure shows the typical alternation of spike and flat top delta waves. As the length of the line labeled "1 sec." indicates, each of the above records covers a period of 7 sec. (*Reproduced from F. A. Gibbs, E. L. Gibbs, and W. G. Lennox, "Influence of the Blood Sugar Level on the Wave and Spike Formation in Petit Mal Epilepsy," Archives of Neurology and Psychiatry*, 1939, p. 1112.)

mal record characteristically shows spikes alternating with "flat-top" delta waves (Type VII). Inspection of these records shows that the motor convulsions are paralleled by cortical potentials of greatly increased speed and amplitude. Such records show how extreme abnormalities of behavior may be correlated with marked electroencephalographic changes.

An abnormal type of electroencephalogram also is found in 75 per cent or more of all epileptic individuals during the typically lengthy periods of time when they are "well," *i e*, not having seizures This abnormality consists chiefly of slow, *delta* rhythms (Type VII), with frequencies ranging from 0 5 to 5 cycles per second As we have said, these waves are of the "flat-top" variety, and they sometimes have smaller waves of higher frequency superimposed upon them This particular phenomenon Lennox[1] calls "dysrhythmia"

Although a substantial majority of epileptics show dysrhythmia, by no means all persons who show dysrhythmia are epileptics It is estimated that the encephalograms of approximately 10 per cent of the population—about 15 million Americans—possess this peculiarity, although only one-twentieth that number—about 750,000—ever have had epileptic seizures The fact that an individual's encephalogram shows dysrhythmia is therefore not an indication that he either has or will have epilepsy However, Lennox believes that cerebral dysrhythmia may indicate a *predisposition* to epilepsy, and he thinks that if an individual's encephalogram reveals dysrhythmia the chances that he has or will have epilepsy are greater than those of a person in whom dysrhythmia is absent For this reason, during the war some neurologists advocated that candidates for admission to the air force who showed dysrhythmia should be rejected, since they might later develop epileptic seizures, particularly under the strains and hazards of flying And recently, in an English law court, the presence of dysrhythmia in a murderer was accepted as evidence supporting his contention that he had committed the crime during an epileptic seizure and thus was not legally responsible for it

Clinicians recognize two principal types of epileptic disorder *essential epilepsy* and *symptomatic epilepsy* In essential epilepsy the cerebral dysrhythmia is thought to indicate the presence of an inherent brain condition which functions as a predisposition to epilepsy Given this inherent predisposition, the seizures may be brought about by various precipitating factors, such as a low concentration of sugar in the blood, kidney disease leading to toxemia (general systemic poisoning), disorders of the pituitary or parathyroid glands, emotional disturbances, and the like In symptomatic epilepsy the dysrhythmia is not constitutional but results from cerebral damage due to such causes as accidental injury to the skull and brain, brain infections, the de-

[1] Lennox, W G *Science and Seizures*, 2d ed New York, Harper 1946

velopment of brain tumors, etc Here, as with essential epilepsy, the seizures may be induced by various precipitating causes Symptomatic epilepsy is much less common than essential epilepsy

The investigation now to be described was based upon the view that cerebral dysrhythmia may be a predisposing condition in most cases of epilepsy Its aim was to test the hypothesis that the disease is a "familial" or heritable one—a hypothesis advanced by Hippocrates 2,300 years ago

THE INHERITANCE OF CEREBRAL DYSRHYTHMIA AND EPILEPSY[1]

PURPOSE

The purpose of this investigation was to test the hypothesis that hereditary factors operate in producing epilepsy Lennox and his associates believe that various characteristics of the cortical potential patterns of an individual depend upon heredity[2] If the cerebral dysrhythmia typical of epilepsy is inherited, then it would be expected that a large number of the near relatives of epileptics would exhibit the phenomenon The specific object of the study was to discover whether this expectation would turn out to be correct

SUBJECTS

The subjects were (1) 94 epileptics, all private patients of the authors, and (2) 183 near relatives of these patients of whom 143 were parents and 4 were children[3] A third group, (3), was a normal

[1] Adapted from Lennox, W G, E L Gibbs, and F A Gibbs Inheritance of Cerebral Dysrhythmia and Epilepsy *Archives of Neurology and Psychiatry*, 1940, vol 44, pp 1155-1183

[2] Some important evidence bearing upon this point comes from the studies of identical twins by Davis and Davis (Davis, H, and P A Davis Action Potentials of the Brain in Normal States of Cerebral Activity *Archives of Neurology and Psychiatry*, 1936, vol 36, pp 1214-1224) And by Lennox, *op cit* These investigators obtained brain-wave records from each member of several pairs of identical twins Davis and Davis present records for 9 pairs of normal twins, Lennox for 7 pairs of abnormal twins, of which 6 pairs had epilepsy In all 16 cases the brain wave records were strikingly similar for both members of each pair of twins Lennox, Gibbs, and Gibbs (The Brain Wave Pattern, an Hereditary Trait *Journal of Heredity*, 1945, vol 36, pp 233-243) have more recently reported observations of 71 "normal" twins, some identical and some nonidentical They found that although the brain-wave records of the normal nonidentical twins were distinguishably different, those of the two members of identical twin pairs were indistinguishable These facts suggest that similarity of wave patterns is largely attributable to similarity of hereditary factors

[3] Parents are more likely than siblings to accompany patients coming from a distance and patients do not often bring their children when they visit the physician, clinic or hospital

group consisting of 76 physicians, technicians, and medical students, and 24 students attending a private school for boys The immediate families of all the members of the normal group were free of epilepsy The investigators suggest that in order to achieve a more nearly complete equivalence of the abnormal and control groups more subjects above forty years of age and more married couples should have been included in the latter group

METHOD

The subjects were seated in easy chairs with eyes closed The room was darkened and shielded to prevent extraneous electrical phenomena from influencing the records Six electrodes were attached to the scalp in a bilaterally symmetrical placement, one over each of the two frontal, the two motor, and the two occipital areas, and "ground" electrodes were attached to the lobes of the ears Leads were taken from the electrodes to six independent amplifiers, so that comparisons of waves from these various cortical areas could be made Recordings were extended over periods of at least 20 minutes, because some subjects whose cerebral potentials are apparently normal when a diagnosis is based upon a recording of short duration may reveal abnormalities when observations are made over a longer time

Interpretation of Records A device known as a "frequency analyzer" was employed in reading and comparing the records Any complex wave may be regarded as a combination of two or more simple waves, and the frequency analyzer makes it possible to determine the frequencies of the component waves

In judging the abnormality of a record at least three characteristics of the wave tracing were considered (1) the dominant frequency (2) the constancy or regularity, and (3) the voltage (amplitude) of the record Sometimes when the record presented a confused mixture of many frequencies, it was impossible to detect a dominant frequency Where a dominant frequency was evident, it was considered to be abnormal in an adult subject if it was slower than 8 per second, or faster than 25 per second Different criteria were used for children, in accordance with the slower normal frequencies typical of lower age levels Elements weighing in favor of a "normal" judgment were the presence of regular 9 or 10 per second rhythms in the occipital or other leads, and the absence of sudden shifts in frequency The degree of abnormality was indicated on a rating scale of four points

RESULTS

Among the 183 relatives of the epileptic patients examined, 60 per cent had definite cerebral dysrhythmia, and 8 per cent had records which were classified as questionable. Thus only 32 per cent of these near relatives of epileptic patients showed brain waves which were found consistently and unquestionably normal. On the other hand, 84 per cent of the 100 normal control subjects gave records which were clearly normal. Only 10 per cent exhibited somewhat abnormal records, and only 6 per cent gave records which were questionable. Thus definite abnormalities of cortical rhythms were found to be six times as frequent in the relatives of patients as in the control group.

Encephalographic records were obtained from both parents of each of 55 patients. In 35 per cent of these the records of mother and father alike were definitely abnormal, and in 60 per cent the record of one parent was abnormal. In only 5 per cent were the records of both parents unmistakably normal.

In a later report,[1] based upon observations on a larger number of cases, similar findings are presented. Electroencephalograms were recorded for 470 near relatives of 140 epileptic patients, including in many cases both parents of the subject. Some kind of abnormality of brain wave was observed in 50 per cent of this group of 470 near relatives, in contrast to 16 per cent of an adult normal control group. Rhythms which were slightly slower or faster than the average were 2.6 times more frequent in relatives than in control subjects, very slow or very fast rhythms were 6 times more frequent than in the control group, and discharges of a seizure type were 8 times more frequent.

DISCUSSION

The results of these studies indicate that the cerebral dysrhythmia typical of epilepsy has a much higher incidence among the near relatives of the epileptics studied than it has among persons not related to epileptics. The authors conclude from this result that the brain condition which is responsible for dysrhythmia—and therefore, in their opinion, for a predisposition to epileptic seizure—is inherited.

However, caution must be observed in interpreting this conclusion. It should be emphasized, in the first place, that the findings of Lennox do not mean that epilepsy itself is inheritable. What the findings

[1] Lennox, W. G. Marriage and Children for the Epileptic. *Human Fertility*, 1945, vol. 10, pp. 95-105.

indicate, rather, is that an abnormal brain condition which is responsible for the dysrhythmia is inherited This inherited brain condition may be conceived as constituting a predisposition to epileptic seizure But the presence of dysrhythmia does not mean that epilepsy necessarily will develop in the given individual The dysrhythmia may only indicate the existence of a condition that makes the individual more likely than the average person to develop seizures if the necessary precipitating factors are present

In the second place, as has already been noted, dysrhythmia and epileptic seizures seem to appear, not only as a consequence of inherited brain conditions, but also because of environmentally caused accidents such as head injuries suffered either at birth or postnatally, neurosyphilis, and other organic nervous diseases In most such cases, it may be presumed that the encephalogram of the patient prior to his injury was entirely normal Only a few of the relatives of such patients show dysrhythmia

In the third place, it is worthy of note that when treatment of epileptic patients—as by various special diets, and sedative drugs—succeeds in reducing the number of seizures, the dysrhythmia also tends to occur with lessened frequency Hence in some clinics E E G tests are made to obtain further indications as to the effectiveness of the treatments given Even if the pattern of cerebral dysrhythmia is determined to some extent by hereditary factors, it appears that it may be altered by chemical means

Finally, one must not assume that these discoveries of Lennox afford any hope for the elimination of epilepsy by eugenic means The prohibition of the marriage of epileptics would have little significance Since epileptics constitute only a small proportion of people with dysrhythmia, the restriction would have little effect on the transmission to offspring of a predisposition toward epilepsy Widening of the marriage prohibition to include all those with dysrhythmia as well as actual epileptics is obviously impracticable since, as has been said, the brain-wave abnormality occurs in about 10 per cent of the population The epileptic person who is contemplating marriage may derive reassurance from Lennox's assertion that the chances that the child of an epileptic parent will be an epileptic are no more than 1 in 40 [1]

[1] Lennox, W G The Genetics of Epilepsy *American Journal of Psychiatry*, 1947, vol 103, p 458

The conception of the inheritance of a predisposition may be applied in connection with a wide range of human traits For example, few if any specialists in the field maintain that the various neuroses and psychoses are directly inheritable A preferable view is that, by virtue of heritable characteristics transmitted through the germ plasm, an organic condition may arise in development, perhaps centering within the nervous system and especially the brain, which makes the individual relatively more likely than most people to have such disorders

The correlation of cerebral dysrhythmia with epilepsy obviously encourages the expectation that similar correlations may be established between particular brain-wave patterns and other psychological and physiological conditions of the organism, both normal and abnormal Of course it is possible that detectable brain-wave patterns represent such psychological and physiological conditions only incompletely and correspond to them only partially But it is also very likely that the methods now employed in the study of brain waves are not sufficiently refined to reveal the extent to which a correspondence exists Present techniques appear to record only the rhythmic discharges of large masses of cerebral neurones acting in unison For example, investigators of cortical action potentials believe that the alpha rhythm observed when a subject is at rest, reflects a massive discharge of such neurones, and that this mass action disappears when the subject becomes engaged in specific psychological activities At such times definite waves disappear from the record, and it is quite probable that this disappearance is due to the fact that different groups of neurones now function in different rhythms, out of phase with each other, so that cancellation effects are produced as far as any obtainable records are concerned A principal deficiency of the methods currently in use is that they do not reveal the minute potentials of single neurones or of small groups of neurones Should it ever become possible to observe and record such potentials—and new technical discoveries may at any time make this feat possible—the scientist would have in his hands an instrument which might at last inform him as to what happens in the nervous system during thinking, learning, and the many other activities which constitute the subject matter of psychology

CHAPTER XIII

THE EFFECT OF DISTRACTION UPON THE PERFORMANCE OF CERTAIN TASKS

INTRODUCTION

Of considerable practical importance are problems relating to the influence of distracting stimuli upon "mental" work and upon attentive attitudes or "mental sets" involved in the performance of tasks. Of especial interest is the problem of the effect upon such processes of auditory distractions, since noises are the most common and the most disturbing annoyances for most people. As Morgan[1] states,

> We know that in the reading of a particularly interesting book we can become entirely oblivious to everything about us, even severe noises. But not one of us will seek a particularly noisy place to take our reading, no matter how interesting it may be. When we enter a reading room we are confronted by the sign "Silence!" If we have some hard mental task, noise becomes really distasteful to us. It is then an important problem to determine just what effect a situation replete with irrelevant noises may have upon our performance. If it is merely a foolish fancy with which we are obsessed when we desire quiet, it is well that we know it. If noise is a hindrance, can it be overcome? If so, at what cost? These and many other questions are worthy of solution.

Perhaps some of these "many other questions" are the following. Does the effect of "distracting" noise depend upon what we are doing, *e g* , the complexity of the tasks, whether much or little in the way of thinking may be involved? Is the radio generally a help or a hindrance to study, or does its effect perhaps depend upon what the radio is playing at the time or upon the nature of the material which is being learned?

Many attempts have been made to determine experimentally the effect of noises upon the performance of various tasks. However, much of the earlier work in this field is open to criticism on several scores. For example, many of the tasks set for the subjects involved

[1] Morgan, J J B The Overcoming of Distraction and Other Resistances. *Archives of Psychology*, 1916, No 35, p 2

responses which, through practice, could be made automatic, that is, performed without thought or without need of continuous attention or concentration, such tasks are unsuited for use in experiments of this kind, since it has been shown that acts which have become automatic are relatively uninfluenced by "distracting" stimuli Furthermore, in such investigations the sounds introduced were generally intermittent, and it is possible that under such conditions important parts of a task can be performed (for example, several sums can be calculated in a series of short addition examples) between the recurrences of the disturbing stimuli

One of the first experiments to be planned in such a way as to remedy these defects was that of Morgan,[1] often quoted in psychological literature dealing with the effects of distraction upon behavior Morgan's procedure was to have each subject perform a task alternately with and without noise distraction, beginning in each case with a period of performance in which there was no distraction The task was a rather complicated one, in which the subjects were required to translate a series of letters into a series of numbers by means of a code which was given them and to respond by pressing keys marked with the numbers in question. The apparatus included an exposure device for displaying the letters and the code numbers, a row of 10 keys, and devices for recording which key the subject had pressed, his reaction time (the time between his seeing the letter and pressing the key), and the amount of pressure he exerted on the key Breathing activities were recorded by means of a pneumograph [2] Various noise-makers were employed, including bells, buzzers, and phonograph records

The principal findings of Morgan's experiment may be summarized as follows

1 With some subjects the initial effect of the noise was to retard the speed of work With other subjects no such retardation was observed

2 When an initial retardation occurred, there was usually an increase in speed during the noisy period, and frequently toward the end of the noisy period the subject exceeded the speed he had attained before the noises were introduced

[1] Morgan, *op cit*

[2] See footnote on p 93

3 More pressure was exerted upon the keys during the noisy periods, suggesting that extra effort was put forth in order to overcome the effect of distraction This increased effort was maintained with fair uniformity throughout the noisy period

4 Spontaneous articulation, that is, whispering or saying the numbers and letters aloud, occurred during the noisy periods These verbal activities may have helped the subject to overcome the effects of the noise

5 There was no consistent increase in errors of performance during the noisy periods

From these results it follows that records of speed and accuracy of performance of a task are not sufficient to show whether one condition is more or less favorable for "mental" work than another Changes in an individual's energy expenditure are also significant in determining the relative advantages of different working conditions Accordingly, it would appear that, after becoming adjusted to a noisy situation, a subject can perform tasks such as those set by Morgan as rapidly and as accurately as in a quiet situation, *but at the cost of a greater expenditure of energy*

Additional evidence bearing upon the problem of auditory distraction was obtained by Ford, whose experiment is reviewed below

I FORD'S EXPERIMENT[1]

PURPOSE

In an experiment similar in many respects to that of Morgan, Ford endeavored to find out whether the introduction and the removal of distracting auditory stimuli would produce changes in efficiency of performance from problem to problem in a series While Morgan had been able to show that often the first few problems in a series performed under conditions of distraction require a longer time for solution than do later ones, he had not made a complete study of the relationship between the position of a problem in a series and the efficiency with which it is solved under distracting conditions The present experiment was designed to yield data which would make it possible to study solution time and accuracy, writing pressure, and

[1] Adapted from Ford, A Attention-automatization an Investigation of the Transitional Nature of Mind *American Journal of Psychology*, 1929, vol 41, pp 1 [illegible]

breathing changes as functions of the position of the problem in a series while the worker is subjected to distracting noise.

METHOD

The Task The subject's task was to note all of the numbers in a row of mixed letters and numerals, to add these numbers as he discovered them, and to write their sum on a strip of paper The following is an example of one of the problems

G d 7 F c 8 N f E a W 9 M B c O P T 5 F z A 4 N V c X z 6 M k h g P 9 x t b

In each example, the numbers were scattered throughout the series of symbols without any predictable order Sixty tasks of this type were devised

The Distractions. Two methods of producing a noise distraction were used In preliminary experiments, performed chiefly with the aim of improving the technique and perfecting the apparatus, a phonograph fitted with a loud needle was employed Its amplifying horn was placed as close as possible to the subject's head The record selected was a humorous monologue delivered in a male voice In the later experiments, a Klaxon automobile horn placed about 2 feet from the subject's ear was used The horn, which was sounded continuously, proved to be more satisfactory as a distractor than the phonograph record used in the earlier experiments

Procedure. The subject sat alone in a room which was relatively free from extraneous and uncontrolled noises A 60-watt incandescent lamp overhead gave a constant amount of illumination, while another 60-watt lamp on the table at the subject's side threw a bright light on the card of problems held in front of him in a rack The electric wiring was arranged so that, without entering the room, the experimenter could turn on this table lamp as a signal for the subject to begin work, and turn it off as a signal for him to stop All recording instruments and control switches were in another room, sound-insulated from the subject

The entire series of 60 problems was placed before the subject on one card, and an endless belt was arranged for exposing the numbers indicating to him the problem which was to be solved next The pushing of a lever by the subject brought a new number into view

and at the same time moved to a new position the strip of paper on which he recorded his answers. This strip of paper was drawn on a spindle so as to run over a wooden plaque, fastened to a sheet of very stiff rubber which had been stretched over a large tambour (*i.e.*, a drumlike chamber). The tambour was connected by means of rubber tubing with a recording tambour in the experimenter's room, so that the subject's writing pressure could be recorded pneumatically on a kymograph drum. The arrangement for recording the subject's writing pressure is shown in Fig. 27. A timing device made dots at 1-second intervals on the same kymograph drum, so that the time required for the solution of each problem could be measured by counting the dots between the mark indicating the presenting of the problem and the mark indicating its completion.
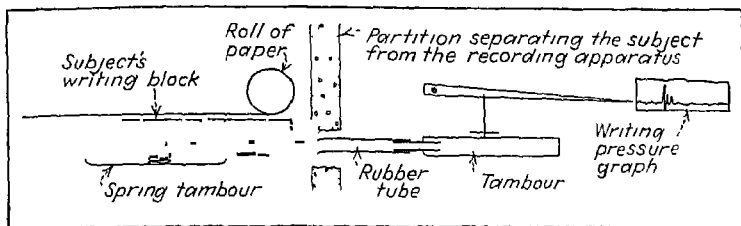
FIG. 27. Schematic Representation of Ford's Apparatus for Recording Writing Pressure.

The procedure involved first telling the subject the nature of the problems and then having him solve one sample problem, so that the process might be perfectly clear to him. After this, the noises were turned on for a moment, that the subject might also become acquainted with the nature of the distraction. The subject was told to work as rapidly as possible, to remember that both speed and accuracy records were being taken, and to try to resist interferences from any source until the signal to stop was given. After receiving the signal to start, the subject worked in succession upon eight of the problems. Then, as he began the next (that is, the ninth) problem, the noise was turned on. The noise persisted for exactly six problems, after which it was abruptly discontinued. Then the subject worked on six more problems under quiet conditions.

After the last problem had been solved, the subject was asked to describe his impressions during the work (his thoughts, feelings, etc.), and all significant "introspective" reports were recorded.

Subjects. Sixteen subjects were used for the preliminary experiments, and forty one for the later (main) experiment All were university students

Treatment of Data. The measurements taken into consideration were those for the six reactions just prior to the introduction of the noise, the six during noise distraction, and the six during the quiet period following the discontinuance of the noise (There were eight reactions in the first quiet period, but the results for the first two were discarded) For each of these series of six problems the time scores, pressure values, and other data for the several subjects were averaged separately for each problem That is to say, the average for all first problems was computed and recorded, then the average for all second problems, etc This made it possible to study reaction time, writing pressure, and the like as functions of the position of a problem in the series

RESULTS

The results may be summarized as follows

Preliminary Experiments, *with the Phonograph Record as the Distracting Stimulus* In these preliminary experiments it was found that

1 No practice effect was evident

2 The initial problem in the distraction period required a conspicuously greater solution time than did any other in the series

3 The six problems of the distraction period considered as a whole required a longer time than did those of either quiet period

4 There was very little correlation between writing pressure and solution time

Later Experiments, *with the Automobile Horn as the Distracting Stimulus* These experiments yielded the following results

1 A definite lengthening of solution time occurred at the beginning both of the noise period and of the following quiet period

2 The initial retardation was more marked at the beginning of the noise period than at the beginning of the subsequent quiet period

3 The fact that the cessation both of noisy and of quiet conditions seemed to function as a distracting occurrence was corroborated by the subject's introspective reports

4 Under the conditions employed, the introduction of auditory distractions had little, if any, effect on the accuracy (that is, the number of errors committed) of the subjects' performance

5 The reduction in speed of performance which resulted from a change of conditions endured longer for slow than for rapid workers

6 Writing pressure increased during the period of noise and diminished from problem to problem during the following quiet period

7 The breathing curves yielded the same evidence of verbal activity during auditory distraction as was found by Morgan

DISCUSSION

One of the most conspicuous features of the records was the evidence of an initial lengthening of solution time, not only at the beginning of the noise period, but also at the beginning of the following quiet period This result is interpreted by Ford as meaning that the onset of *both the noise and the quiet constituted distractions* Since, when the automobile horn was used, the initial slowing was greater at the beginning of the noise period than it was at the beginning of the following quiet period, it may be concluded that the noise was more distracting than was the ensuing change to absolute quiet Nevertheless, it is clear that the cessation of the noise was genuinely disturbing to most subjects In this connection the introspective reports are very significant For example, subjects reported that when the quiet period began they missed the noise and wished it had not stopped, or that when the horn stopped sounding they were astonished because they had forgotten it was in operation Others said that they "missed the racket" and were bothered by the "uproarious quiet," that they could "hear the silence," etc Often subjects would report that they wished the noise would stop, but when it did stop they then said they wished it had not done so Some subjects reported that they had liked the noise because it produced an exciting effect Most of the subjects were certain that they had worked more slowly during the noisy period and were equally sure that they had worked somewhat faster when the noise had stopped However, the results showed that this had not been the case

As we have pointed out, not only the noise but also the change from noise to quiet was distracting to the subjects From this it may be inferred that any marked change in the general pattern of stimulation under which a person is working can constitute a distraction Noises are commonly disturbing But they are disturbing, not so much because they are noises, as because they usually occur intermittently

and therefore continually alter the general stimulus pattern to which one is reacting

Like Morgan, Ford found that auditory distractions had little or no effect on errors Furthermore, he found that the effect of the distraction was about equal for fast and for slow workers in the first problem of the noisy and of the quiet periods But the fast workers recovered very quickly from the effects of the distractions, whereas the slow workers did not recover until they had almost completed the entire series of six problems Apparently, the slow workers had exceptional difficulty in building up a stereotyped, routine resistance to distraction, a disability which may well be one cause for their characteristically slow pace of performance

We have in Ford's data evidence that the initial reactions of a series are highly susceptible to interference from new sources of stimulation but that the later reactions of the series show recovery from the effects of such interference Further analysis of these data shows that the solution time and the writing-pressure values changed from problem to problem throughout the series in such a way as to form definite gradients, that is to say, the pressure increased gradually during periods of noise and diminished gradually during quiet periods This fact suggests that resistance to distraction is not based upon some change in the organism which occurs suddenly and all at once, but rather that it develops gradually, as if it were a process of habit formation and of learning

II FURTHER STUDIES OF ENERGY EXPENDITURE AND OF MUSCULAR TENSION UNDER DISTRACTION

The occurrence of increased energy expenditure, as evidenced by increased muscular tensions during periods of auditory distraction, is of course of great interest from a practical as well as from a theoretical point of view Subsequent to the pioneer studies of Morgan and Ford, several investigators have attempted to study energy expenditure under distraction by measuring metabolic rate,[1] and to study muscular

[1] Metabolic rate is the rate at which nutritive substances are assimulated and built up into living protoplasm within the organism on the one hand, and the rate at which, on the other hand living matter is broken down into simpler products It is measured in terms of the rate at which oxygen is consumed by the individual In order to make this measurement, the subject's nose is closed with a spring clip, and a special mouthpiece is provided through which oxygen is inhaled from a reservoir and carbon dioxide

tensions as recorded by action-potential techniques.[2]

In 1939 Freeman[3] published laboratory findings obtained through the use of both of these methods. Freeman had been impressed by an apparent incompatibility in the results obtained by different investigators concerning the energy costs of mental work performed under distraction. On the one hand, Morgan had reported *a sustained increase in muscular tension*, and *Ford a progressive increase in tension* under distraction. On the other hand, in another study, Davis[4] had found that although noise stimulation produced an increase in the magnitude of the action potentials recorded from the right arms of subjects who were solving problems, the tension thus indicated diminished as the noise continued, instead of increasing further or remaining at its initial high level. Harmon[5] had shown that the subject's metabolism per unit of work done increased when noise was first introduced, but noted that in a relatively short time the worker tended to return to the metabolic rate characteristic of work under conditions of quiet. A possible explanation of this seeming incompatibility of results was suggested by Poffenberger,[6] who said:

> One might accept the increased tensions noted by Morgan as authentic, and interpret the reduced tensions demonstrated by Davis as a *shift of tensions* to new muscles with a reduction of tension only in those muscles on which measurements were being made at the time. The decreasing metabolic cost as adaptation to the distraction progressed would indicate merely that the later tension patterns functioned more economically than the earlier ones,—that is, with less expenditure of energy.

In Freeman's experimental situation, subjects solved problems in addition successively under conditions of quiet and of noise stimu

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and unused oxygen are exhaled into a chamber containing soda lime. The carbon dioxide is absorbed by the soda lime, and the unused oxygen is returned to the oxygen reservoir. Since metabolic rate is a function of rate of oxygen consumption, an index of metabolism may be obtained by determining the rate at which oxygen is drawn from the reservoir.

[2] Freeman, G. L. Changes in Tension-pattern and Total Energy Expenditure during Adaptation to Distracting Stimuli. *American Journal of Psychology*, 1939, vol. 52, pp. 354–360.

[3] See pp. 216–218 for a description of action-potential techniques.

[4] Davis, R. C. The Muscular Tension Reflex and Two of Its Modifying Conditions. Indiana University Publications, Science Service, 1935, No. 3, pp. 1–23.

[5] Harmon, F. L. The Effect of Noise upon Certain Psychological and Physiological Processes. *Archives of Psychology*, 1937, No. 147.

[6] Poffenberger, A. T. Some Unsolved Problems in Human Adjustment. *Science*, 1938, vol. 87, pp. 124–129.

lation, with rest periods preceding the work periods. Records were obtained over a period of 12 days. Determinations of oxygen consumption were made both during rest periods and during quiet and noisy work periods, and records of muscular action potentials were made independently for each of the subjects' four limbs. As is usual in experiments of this kind, it was found that the introduction of a noise distraction was followed by a reduction in work output, but that this reduction was only temporary and that no decrease in accuracy occurred. In addition, analysis of the action-potential records revealed evidence of shifting tension patterns, as Pottenberger had suggested in his interpretation of Harmon's results. The indications were that the immediate effect of noise distraction was to bring about increased and widespread bodily tensions, and that this change was paralleled by an increase in oxygen consumption. With continuation of the distracting noises, however, the tensions became more or less limited to the parts of the body used in the performance of the task, and as the tensions became less widespread, energy expenditure as measured in terms of oxygen consumption dropped to a lower level.

III. THE INFLUENCE OF MUSIC DISTRACTION UPON READING EFFICIENCY: FENDRICK'S EXPERIMENT

PURPOSE

While many investigations of auditory distraction have been carried out as laboratory studies, observations have also been made in the office, the classroom, and the factory. Of especial interest to students is the experiment of Fendrick,[1] the aim of which was to determine the influence of radio or phonograph music upon reading speed and comprehension. This investigator notes that both students and laymen express varying opinions concerning the way in which their reading comprehension is affected by the radio. For example, Cantril and Allport[2] report that when 142 college students who owned radios responded to questionnaires, 68 per cent of them said that they *believed* that their study was less effective when the radio was "on." Most students reported, however, that music interfered with study less than speeches did, and that when they decided to have the radio on while studying they generally selected a musical program. This is

[1] Adapted from Fendrick, P. "The Influence of Music Distraction upon Reading Efficiency," *Journal of Educational Research*, 1937, vol. 3, pp. 264-271.

[2] Cantril, H., and G. W. Allport. *The Psychology of Radio*. New York, Harper, 1935.

precisely what one might expect, in view of the fact that the auditory language patterns of a radio speech probably interfere more directly than does music with the visual language patterns characteristic of reading

The aim of Fendrick's investigation was to measure the difference in reading or study efficiency that might manifest itself when college students were asked to study a selected assignment in the classroom with and without distraction by phonographic music

METHOD

Subjects. While Morgan, Ford, and Freeman had employed the single-group method of experimentation, Fendrick used the equivalent-group method [1] The groups were two sections of college sophomores registered in a course in introductory psychology One section containing 61 students served as the control group (the group which was to work without distraction), the other, composed of 62 students, constituted the "experimental" group The two groups were equated with respect to chronological age, and their average scores on a test of intelligence were approximately equal

Procedure. Each section was given as the study assignment a 12-page mimeographed chapter abstracted from a psychology textbook which the students had not seen previously A period of exactly 30 min was allowed for study of the chapter While the control group worked under quiet conditions, music from phonograph records was used as the distractor for the experimental group, since it was not possible to get the desired kind of radio broadcast at the time chosen for the experiment The records selected provided lively semiclassical music

Promptly after the end of the study period a 60-item true-false test on the contents of the chapter was given Fifteen minutes were allowed for the answering of the questions Each student was asked

[1] The "single group" method involves the use of one group of subjects Each subject performs and is observed or tested under the two or more conditions imposed in the experiment, for example, with and without distraction The "equivalent-group" method makes use of two or more groups of subjects so selected that if the groups were to perform under identical conditions, the averages and measures of variability would be the same for the groups Equivalent groups must therefore be equal with respect to average age, intelligence, or any other factor which might be related to the performance or capacity being measured One group then performs under one set of conditions while the other performs under different conditions The results of the two groups are then compared

to indicate on the test blank the number of pages he had read in the 30 min. period. He also was asked if playing the radio while he was studying usually annoyed, pleased, or made no difference to him.

The subjects in both groups were divided into five subgroups according to their quintile ranks[1] on the above-mentioned intelligence test, and the average "comprehension" scores on the true-false test for experimental and control subjects within each quintile intelligence group were compared.

RESULTS

Fifty per cent of the subjects reported that usually they did not like to study with the radio on, 25 per cent said they did like to study with the radio on, the remaining 25 per cent reported "indifference."

The results of the reading comprehension tests are summarized in Table I.

TABLE I

Average Comprehension Scores for Control and Experimental Subjects, Differences between Control and Experimental Averages, Standard Errors of the Differences, and Critical Ratios

	Quintile rank, by intelligence					Total, all subjects
	I	II	III	IV	V	
Average scores in quiet condition	22.50	30.54	35.25	36.00	38.63	33.69
Average scores in noise condition	22.13	24.08	31.58	31.67	33.83	29.58
Difference between averages	0.37	6.46	3.67	4.33	4.80	4.11
Standard error of difference	3.56	3.58	2.77	2.32	2.21	1.57
Critical ratio	0.1	1.8	1.3	1.9	2.2	2.6

It may be noted that, although some of the critical ratios[2] are small, the difference in every quintile group favored the nondistracted subjects. The difference of 4.11 points between the groups as wholes has a critical ratio of 2.6 and therefore possesses a considerable degree of statistical significance. Statistically speaking, the chances are about 97 in 100 that a repetition of the experiment would yield a difference in the same direction.

[1] If the members of a group are arranged in order of standing with respect to some trait, those in the lowest fifth of the group are said to fall within the first quintile, those in the second fifth are said to fall in the second quintile, etc.

[2] See footnote on p. [illegible]9 for a definition of "critical ratio."

The results also show that, with the exception of the difference for the second quintile subgroup, there is a gradual increase in the size of the differences between the average scores for distracted and nondistracted subjects as the level of intelligence becomes higher. This suggests that distractors of the kind employed in this experiment have a greater disturbing effect for subjects at higher levels of intelligence.

Although the average comprehension scores were higher for the nondistracted groups, the distracted subjects read a greater amount of material. Of the nondistracted subjects, only 17, or 28 per cent, read the entire assignment during the 30-min. study period, whereas 26, or 43 per cent of the distracted group, finished the reading. However, since the critical ratio of the difference was only 1.8, we cannot be confident that repetition of the experiment would not yield a difference in the opposite direction. Also, it is apparent that although the distracted group read more pages during the 30-min. study period, what advantage they gained thereby is not clear, in view of their inferiority in reading accuracy and comprehension.

DISCUSSION

Fendrick's experimental results indicate that auditory distraction of the kind employed by him does have an adverse effect, at least for most subjects, upon reading comprehension as measured by scores on an immediate true-false test. However, several questions remain unanswered. Is there an adaptation process in the "reading-with-distraction" situation, comparable to the adaptation observed by Morgan, Freeman, Ford, and others? It may be that the music exerted its greatest effect early in the period and that some adaptation occurred later on. The way in which the experiment was planned does not make it possible to answer this question. Furthermore, it is possible that the actual effects of the auditory distraction were quite different for different subjects of the experimental group. The music may have had little or no effect upon the reading comprehension of some of the subjects, a moderate effect upon that of some, and a relatively large effect upon that of others. The differences in the group averages for distracted and nondistracted subjects *may* be attributable largely to pronounced effects which the distraction had upon a few individuals, or it *may* be attributable to a moderate effect of distraction upon all or nearly all of the distracted subjects. Only a single-group

method of experimentation could give us information concerning the effect of distraction in individual cases

IV NOISE IN INDUSTRY

Psychological literature contains many reports on observations concerning the effect of noise on work in offices and factories. For example, Kornhauser[1] compared the productivity of the same four typists when they were working in quiet and in noisy offices No significant differences were observed with respect to errors, amount typed, or number of letters discarded because of numerous mistakes in them In another office study, however, a noise reduction of 14 5 per cent brought about an increase of 8 8 per cent in the work output of typists and a decrease of 24 per cent in the number of errors committed The noise reduction also decreased employee turnover by 47 per cent and absenteeism by 37 per cent It is possible that in the latter situation the amount of auditory stimulation which prevailed before reduction was greater than the amount present under Kornhauser's noisy condition In one factory study using as subjects workers assembling temperature regulators, it was found that moving their work from the vicinity of a boiler shop to a quiet area increased their production more than 37 per cent and decreased errors by one-eighth [2]

It would seem that, although in industry noise does not always diminish productivity, it *does not increase production*, as it did in some of the laboratory experiments after adaptation to noise had occurred It has been suggested that this difference may be attributable to a difference in motivation People are capable of working as well during noise stimulation as during a quiet period, but they must be strongly motivated to do so

Various other reports[3] indicate that music has a favorable effect upon the productive efforts of factory workers when the tasks performed are simple and repetitive and have become automatized It is even probable that in such a work situation, a limited distraction in the form of enjoyable music helps to lessen monotony and to maintain a more favorable attitude on the part of the worker

[1] Kornhauser, A W The Effects of Noise on Office Output, *Industrial Psychology*, 1929, vol 2 pp 621–622

[2] Anon *Industrial Psychology*, 1928, vol 3, p 323

[3] Smith, H C Music in Relation to Employee Attitudes, Piecework Production, and Industrial Accidents *Applied Psychology Monographs* 1947 No 14

Conclusions

Earlier we noted Morgan's question whether our desire for quiet is "merely a foolish fancy with which we are obsessed," and "If noise is a hindrance, can it be overcome? If so, at what cost?" The findings of his investigation and of the studies of Ford, Freeman, and Fendrick provide a basis for answering these questions. The normal desire for quiet conditions of work can scarcely be regarded as a "foolish fancy." Seemingly, noise is usually somewhat of a hindrance, at least at its onset. Its effects can be overcome, but only at the cost of what often is a considerable expenditure of energy. Furthermore, we must not disregard the possibility that the individual's increased tension in maintaining his habituated adjustment to an originally "distracting" stimulus may eventually be detrimental to health. Nevertheless, it is clear that if we become adjusted or adapted to a constant noise, its sudden termination may also constitute a distraction, at least temporarily. Hence the fundamental characteristic of a stimulus that we call "distracting" is that it constitutes a change with respect to previous conditions of stimulation.

The question whether or not the practice of studying to the accompaniment of the radio is a desirable one is difficult to answer at this time. An individual who had formed this habit would probably be "distracted" if the radio were turned off. However, it also seems very likely that studying under such circumstances usually requires a greater expenditure of energy and that the habit is therefore an uneconomical one for most people.

CHAPTER XIV

A COMPARISON OF THE INTELLIGENCE OF "RACIAL" AND NATIONAL GROUPS IN EUROPE

INTRODUCTION

The development of intelligence tests and their popular acceptance as a means of differentiating *individuals* of different levels or degrees of intellectual capacity have led to the attempt to employ these instruments for a variety of other specific purposes, among them the discovery of whether or not there are "superior" and "inferior" *races* of mankind. The hypothesis that some racial groups are inherently (*i.e.*, by heredity) more intelligent than others is commonly held. This hypothesis, however, is one which cannot easily be tested, first, because of the difficulty of securing a test of intelligence which will be equally valid as a measuring rod for individuals of widely different cultural backgrounds, and, second, because of the difficulty of identifying and isolating these so-called "races."

One obstacle in the way of securing a universally applicable measure of intelligence is, obviously, the language in which the test is constructed. For example, if the original Binet test is to be used with children in the public schools of Shanghai, it must first be translated into Chinese. The adequate translation into English of those parts of the test which were originally written in French presented certain difficulties. These difficulties are greatly increased when the translation must be made into a particular dialect of Chinese (or Aleut, or Bushman, or Fiji). But the difficulties of "translation"—if the test is to be equally fair[1] to the children of the various groups under comparison—go far beyond those dependent upon language differences alone. For example, in Shanghai the coins used in one part of the test can no longer be American ones. And even when we have selected

[1] A test may be said to be equally fair to the individuals or groups under comparison if performance on it is not significantly affected by *differences* among them in past experience, *i.e.*, in education, in culture, in socioeconomic status, etc.

Chinese coins for use with the Shanghai children, have we the right to assume that the test is now as fair for them as it is for American children, that is, that the familiarity of Chinese children with the Chinese money system, based on the frequency with which they handle and use Chinese coins, is as great as is that of American children with the American money system? And how is one to "translate" this test item for the children of a culture in which coins are not used at all? One encounters difficulties of equal magnitude in attempting to adapt many of the items included in any intelligence test standardized in a particular cultural group for use with the members of another. The specific objects pictured in an "object recognition" test (*e.g.*, a bicycle, a glove, etc.) may be less common in one culture than in another, or familiar in *different* forms or shapes, or even completely unknown. The situations presented in a test of ethical discriminations may be susceptible of translation into the language of a particular group, but obviously, if the system of morality of that culture is a markedly different one, the test is simply not applicable. Furthermore, the validity of a given test item may vary considerably even for different groups of children who speak the same language and live in the same country. For example, the following incomplete sentence is an item in an intelligence test which has been widely used in the United States:

should prevail in churches and libraries.[1]

The expected completion is the word "Silence." This may be a fair question for twelve-year-old New York City children, but it is wholly unfair to Southern rural Negro children, many of whom have never seen a library, and many of whom are members of "revivalist" sects, who judge the "success" of a church meeting according to the amount of vociferous participation by the congregation.

There are other more deep-seated differences among various cultures which may render difficult or impossible a comparison of the intelligence of the different cultural groups on the basis of their performance on any given test. In certain societies, for example, great value is placed on the careful, meticulous execution of tasks, and there is little or no interest in the length of time taken to complete them, provided the product is of high quality. People of such cultures cannot validly

[1] National Intelligence Test, Scale A, Form 1, Test 2, item 20.

be examined by any of the many psychological tests in which speed of performance is a criterion of ability and constitutes one of the bases for computing the test score.[1] Another deeply rooted cultural difference is in the degree of motivation (and therefore of effort one is willing to expend) in meeting such situations as intelligence tests present. Children bred in societies in which the stress on the importance of winning the approval of adults which characterizes our society is less emphatic or virtually absent may be far more lackadaisical in their attitude toward the test situation. Finally, there are cultures in which individual competitiveness plays a much smaller role than it does in the United States,[2] cultures in which group *mores* encourage a great deal more of mutual aid, consultation among individuals, and the cooperative performance of activities. Psychologists and anthropologists who have attempted to test the intelligence of members of such societies have reported that the subjects were often surprised and disappointed that they were not permitted to help each other on the examinations. Confronted by a strange situation, and deprived of their habitual recourse to assistance by their friends and relatives, they tended to lose interest in the tests.[3]

Although the factors which have been discussed do not exhaust the list of culturally based differences among people which inevitably affect the nature of their performance on intelligence tests, they furnish sufficient evidence for seriously mistrusting the validity of any intelligence test standardized on a "population sample" of a given nationality or "race" for the members of any other national or "racial" group.

The second fundamental difficulty in the comparative measurement of racial intelligence is the problem of the identification of the races. Normally, it is relatively easy to determine the *nationality* of an individual: he is, usually, one of an aggregate of people living under a common governmental system and occupying a geographical area

[1] A culture in which speed in the performance of tasks usually is not deemed important, largely because time means little or nothing, is that of the Yakima Reservation Indians. See Klineberg, O., An Experimental Study of Speed and Other Factors in "Racial" Differences, *Archives of Psychology*, 1928, No. 93.

[2] An example of such a culture is that of the American Zuni, described in Chap. IV.

[3] A group of Australian aboriginals who behaved in this manner under test conditions is described in Porteus, S. D., *The Psychology of a Primitive People: A Study of the Australian Aborigine*, New York, Longmans, 1931.

which bears the national name[1] Nations, however, are not races, and the problem of the definitive designation of a given individual's *race* is a far more complex one Different groups of mankind, occupying various areas of the earth, exhibit obvious intragroup similarities and intergroup differences in certain traits of physique, primarily in color Some ethnologists have differentiated "races" of men on the basis of skin color alone Others have attempted more elaborate "racial" differentiations—for example, distinctions between subdivisions of the white race (*i e* , the Mediterranean, the Alpine, and the Nordic "racial" types) on the basis of the principal geographic distribution of people who show differences in such traits as eye and hair coloration head proportions, and stature Most scientists are agreed that such anatomical differences derive in large measure from inherent (*i e* , hereditary) factors But there is considerable disagreement regarding the validity of two inferences which some writers have drawn from the foregoing facts first, that groups of people who show distinctive physical traits constitute different "stocks" or "strains" of mankind, analogous to different breeds of dogs, or of beef cattle, or of other infrahuman animals, and, second, that differences in significant psychological traits (*e g* , in intelligence) are associated with the observed anatomical differences

Actually, throughout the period of recorded history, and doubtless also for the ages during which men lived on the earth without leaving chronicles of their existence, there have occurred countless invasions, migrations, and emigrations of people inhabiting certain terrestrial areas (and showing particular anatomical traits) to other regions, inhabited by people showing different physical characteristics Some of these migrations have involved very large, others smaller populations, some have occurred over vast distances, others over more limited ones Through the centuries Europe has undergone successive invasions, such as those by the oriental Huns, by the Mongolian followers of Genghis Khan, and by the Moors The ancient Greeks and Romans invaded Asia and Africa At different times, also, the Romans migrated into Gaul, Britain, western Germany, and Spain north Europeans overran Greece, Asia Minor, and northern Africa,

[1] The definition of nationality (*i e* , of citizenship) is not always so simple, as, for example, in the case of the many thousands of "displaced persons" following the Second World War

and spread westward to Italy and Spain, the Goths and other Germanic tribes, forced out of northeastern Europe by pressure from the Mongolians, spread into Italy and France, and into southern and western Europe generally England has been conquered and occupied at various times by the Romans, the Angles, the Saxons, the Danes, and the Normans Whether these great movements of men occurred by peaceful migration, by invasion and conquest, or by forced translocation (for purposes of colonization or of slave labor), intermixing of the alien with the native populations inevitably occurred Within the United States, for example, despite social and legal barriers of various sorts, there has been a continual interbreeding of Negroes and of Indians with each other and with the varied white and mongolian populations which have immigrated to this country from the beginning of its history In view of the fact that Asia and Africa, like Europe and the Americas, have been the scene of many similar migrations and invasions, it is not surprising to learn that in the opinion of almost all ethnologists the existence at present of any pure "racial stock" (apart from a few groups, such as the inhabitants of Iceland and the Australian Bushmen, that live in geographically isolated areas) is extremely unlikely

Nevertheless, many people persist in thinking of mankind as composed of "pure racial types," and, moreover, consider that certain of these "races" are superior to others[1] Adolf Hitler, for example, was not the first and surely will not be the last person to assert the doctrine of the superiority of "the Nordic" to all other men The investigation presented below[2] represents an attempt to test the validity of allegations such as these Specifically, Klineberg's aim was to study the

[1] It is a "difficult task to establish any race as either superior or inferior, but relatively easy to prove that we entertain a strong prejudice in favor of our own racial superiority " (Kroeber, A L *Anthropology*, p 85 New York, Harcourt Brace, 1923)

"As one becomes immersed in the study of racial psychology one comes to realise that the significant factor involved is not by any means the psychical differences of the races, but rather the psychical unity of man What counts and demands attention is not the problematical difference in racial ability, but the disability of the genus Homo, however sapiens, to think intelligently and without prejudice in this field, so heavily charged with emotion vanity, special pleading and still lowlier affects " (Goldenweiser, A *Anthropology*, p 36 New York, Appleton-Century-Crofts, 1938)

See also Linton, R , ed *The Science of Man in the World Crisis* New York, Columbia University Press, 1944

[2] Klineberg, O A Study of Psychological Differences between "Racial" and National Groups in Europe *Archives of Psychology*, 1931, vol 20, No 132

intelligence of samples of the "Mediterranean," the "Alpine," and the "Nordic" divisions of the Caucasian race

The *Nordic type* is said to be distinguished by a long head and face, light hair and eyes, and tall stature The *Alpine type* is described as having a round head and face, brown hair, and as being medium in height The *Mediterranean type* is described as having a long head and face, dark eyes, dark brown (or black) hair, and as being somewhat shorter in stature than the "Alpine" On the basis of the prevalence of these three types of physique in the population at large, the three European "races" are found to occupy roughly horizontal belts on the map of Europe Individuals of the "Nordic type" are distributed principally around the North and Baltic Seas, "Alpines" predominate in the region of the Alps, individuals of the "Mediterranean type" live along the shores of the Mediterranean Sea The "Nordic type" is found in relatively large numbers in the Scandinavian countries, in England and Scotland, Holland, northern Germany, and northern France The "Alpine type" predominates in Switzerland, Austria, southern Germany, central France, northern Italy, Russia, and Poland The "Mediterranean type" is most frequently found in the populations of Spain, Portugal, Greece, southern Italy, southern France, and northern Africa Of course, many people who bear the physical characteristics of each of these "races" are found also in regions where the other "races" predominate

KLINEBERG'S STUDY OF THE INTELLIGENCE OF NATIONAL AND "RACIAL" GROUPS IN EUROPE[1]

THE SUBJECTS

The Seven Rural Groups. Klineberg attempted to obtain as "pure" samples of the three European "races" as could be secured France, Germany, and Italy were selected "because each one of these is made up of at least two of the three European 'races' (France of all three) so that comparisons might be made between different racial groups within the same nation, as well as between different [national] samples of the same racial group" (page 13) Because there is a greater mixture of "types" in cities, "racial" comparisons were made between rural groups only

[1] Adapted from Klineberg, *op cit* See also the chapter by Klineberg in Linton, ed, *op cit*, pp 63–77

The subjects were all boys, ranging in age from ten to twelve years inclusive. In order to get the "purest" possible samples in sufficient numbers, the study was carried out in those places where individuals who possessed the physical characteristics which are attributed to the "race" under survey were found in greatest concentration. Furthermore, Klineberg selected only children who possessed the physical traits generally considered typical for the given "race," who had been born in the given area, and whose parents had been born there, also.

Three localities in France were selected: a northern district where the characteristics imputed to the "Nordic" are conspicuous in the population, one in the Alpine region, and one in southern France where the "Mediterranean type" prevails. In Germany, a section in the province of Hanover in northwestern Germany was selected for the "Nordic" area, and a section in the Black Forest of Baden for the "Alpine." In Italy, the "Alpine" sample was taken from an area near Turin, and the "Mediterranenean," from a region near Palermo, in Sicily.

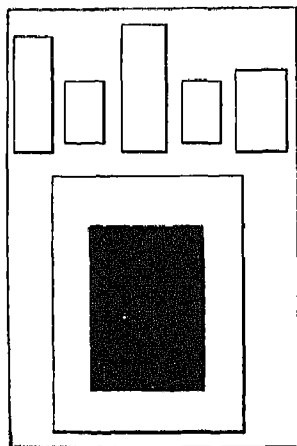
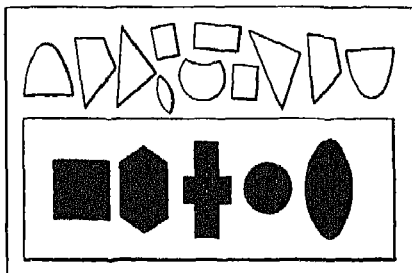
In this way, seven "racial" groups were formed: two "Nordic," three "Alpine," and two "Mediterranean," with 100 boys in each group. None of the subjects came from a town with a population of over 3,000. For the selection of his subjects Klineberg adopted the following procedure. In the case of each community, he first collected all the boys who fell within the age range. He then eliminated boys who had been born outside the community or whose parents had been born outside the community, as well as all boys who did not possess the typical physical characteristics of the "race" in question. Every child who was finally placed in a "Nordic" group had fair hair, blue or light-gray eyes, and was long-headed (dolichocephalic) as determined by cranial measurements. Every boy included in the "Alpine" group was brachycephalic (round-headed), and was neither very light nor very dark in eye and hair coloration. Every "Mediterranean" boy had dark hair and eyes and was dolichocephalic. The investigator considered the criterion of stature inapplicable, since the subjects were not fully grown.

The fathers of the boys were, for the most part, peasants and farmers, laborers, wood-cutters, fishermen, and fruit dealers.

The Three City Groups. In each of the cities of Paris, Hamburg, and Rome, 100 boys were selected in order to compare the test scores

of the urban with those of the rural children Four schools in each of the cities were visited From each school 25 boys falling within the required age range were selected at random These children did not have to belong to any "racial type," but merely had to be natives of the city in which the study was made The principal occupations of the boys' fathers were those of mechanic, clerk, laborer, merchant, factory hand cabdriver, and waiter

THE TESTS

Klineberg used six nonlanguage performance tests of the Pintner-Paterson series These were the Triangle Test, the Healy Puzzle 1, the Two Figure Form Board, the Five Figure Form Board, the Casuist Form Board, and the Knox Cube Test All of these excepting the Knox test are form-board tests in which the task is to put blocks of wood together in such a way as to fill cutouts in the board There is a 5-min time limit for each of these tests Records are kept of the time required to complete each form board and of the number of errors made The five form-board tests are shown in Fig 28 In the procedure for the Knox Cube Test the experimenter touches four cubes on a table with a fifth cube, in certain predetermined orders The subject attempts to repeat the series of movements exactly, and the number of his successes is recorded

All of Klineberg's subjects were tested individually The writer himself gave all the tests, except for the work in Hamburg and Rome, where for a time he was assisted by university students

RESULTS

The scores obtained on the six tests were combined for each child into a composite score, so that the "general intelligence" score of each child was indicated by the total number of points he received Table I gives the average score for each of the 10 groups, arranged in order from highest to lowest The number of subjects in each group was 100

City and Country Differences. A marked and statistically reliable difference[1] was found between the scores made by the city and country children The three highest groups were the city groups Among

[1] The meaning of the statistical reliability of a difference is explained on p 9

FIG. 28 Five of the Six Pintner-Paterson Nonlanguage Performance Tests Which Klineberg Used

In each diagram, the darkened areas within the rectangular board are the cutouts, and the small geometrical forms above the board are the wooden blocks with which the cutouts are to be filled

the city groups the differences proved to be small and unreliable although the largest difference, that between Paris and Rome, has 87 chances in 100 of being a true one On the other hand, the difference

TABLE I

Intelligence-test Scores of the Three Urban and the Seven Rural Groups

Group	Average score	Median score	S D[1]
Urban			
Paris	219 0	218 9	46 2
Hamburg	216 4	218 3	45 6
Rome	211 8	213 6	42 6
Rural			
German "Nordic"	198 2	197 6	49 0
French "Mediterranean"	197 4	204 4	45 6
German "Alpine"	193 6	199 0	48 0
Italian "Alpine"	188 8	186 3	48 4
French "Alpine"	180 2	185 3	46 6
French "Nordic"	178 8	183 3	56 4
Italian "Mediterranean"	173 0	172 7	54 2

[1] The standard deviation (S D) is a measure of variability which is computed by obtaining the deviation of every individual score from the average, then squaring each deviation, finding the average of the squares, and extracting the square root of that average

between the poorest city group and the best country group was found to be highly reliable, the chances being 98 in 100 that there is a true difference

TABLE II

Intelligence-test Scores of All the City and Country Children

Group	Average score	Median score	S D	Number
City	215 7	216 9	45 1	300
Country	187 1	187 0	50 9	700

This difference in favor of the urban over the rural groups becomes especially clear when all the groups of each type are combined The averages for the combined groups are given in Table II

The observed superiority of the city children in these six *performance tests* is in accord with the results of many other investigations in the

United States and in other countries in which urban children have regularly been found to excel rural children in standard *language tests* of intelligence. As will be seen later, this city-country difference is far more significant statistically than are any of the differences which the experimenter observed between "racial" and between national groups.

"Race" Differences. An examination of the data in Table I shows that of the seven national samples, the three which obtained the highest ranks comprised one "Nordic," one "Mediterranean," and one "Alpine" group. However, since the differences among the scores of these groups were very small and, moreover, proved to be statistically

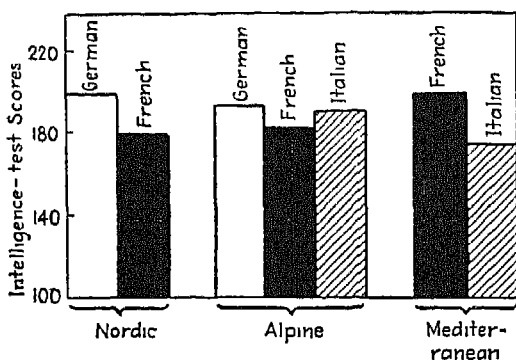



Fig. 29. A Graphic Presentation of the Average Intelligence-test Scores Obtained by the Various National Samples of Each of the Three "Racial" Groups

unreliable, the groups may be considered about equal in their performance on these tests. Furthermore, it is to be noted that one sample of each of these three "racial" types also ranked relatively low. Finally, it is important to observe the wide differences among different national samples of the same "race." These differences are shown graphically in Fig. 29. From the data for the tests given in Germany, the superiority of the "Nordics" over the "Alpines" is negligible. In Italy, the "Alpines" appear to be superior to the "Mediterraneans", but in France, the "Mediterraneans" are superior to the "Alpines" and both are superior to the "Nordics." In fact, in France the "Nordic-Alpine-Mediterranean" hierarchy which sometimes has been asserted to exist is completely reversed, and the difference in favor of the "Mediterranean" over the "Nordic" average is

almost completely reliable (99 5 chances in 100), there is a completely reliable difference between the medians In other words, there is no consistent superiority of one "racial" group over another, the hierarchy depends on the particular "Nordic," "Alpine," and "Mediterranean" samples studied

If all the subjects are classified according to "race," without regard to nationality, the resulting averages and median scores for the different "racial" groups are as given in Table III

TABLE III

Intelligence test Scores of the Three 'Racial" Groups

Group	Average score	Median score	S D	Number
"Nordic"	188 5	190 5	53 4	200
'Alpine"	187 5	190 2	48 4	300
Mediterranean"	185 2	188 5	51 8	200

A survey of Table III shows that the scores for the three "races" were practically identical The differences are insignificant and "none of them even approach reliability" Klineberg concludes that, "As far as these results go, the quite insignificant differences between the 'races,' the wide variations found within the same 'race,' and the fact that a 'racial' hierarchy found in one nation does not hold for another, indicate that the concept of 'race' when applied to these European groups has no significance in relation to the kind of differences demonstrated by performance tests in this study" (page 31)

National Differences If the three city groups are ranked in the order of scores obtained by the subjects selected from each, Paris is first, Hamburg next, and Rome last, with only slight and unreliable differences among them If the rural groups are combined according to nationality, we find, as Table IV shows, that their rank is German first, French second, and Italian third

The difference found between the scores for rural groups in Germany and for corresponding groups in France and Italy is almost entirely reliable, since there are respectively 99 9 and 99 4 chances in 100 that true differences exist On the other hand, the difference between the French and the Italian rural groups is unreliable Analysis of Kline-

berg's data discloses a considerable amount of variability within the French and within the Italian rural groups As can be seen from Table I, the Italian "Alpines" score much closer to the two German groups and to the French "Mediterranean" group than they do to the Italian "Mediterraneans" Similarly, the French "Mediterranean" group resembles both German groups in intelligence much more closely than it does the other French groups. *It would seem, therefore, that the fact of nationality, as such, is not a factor determining the intelligence level of any national subgroup* As Klineberg puts it, "There is so much variability between different samples of the same national group, and in many cases so much similarity between samples of

TABLE IV

Intelligence-test Scores of the Rural Samples of the Three National Groups

Group	Average score	Median score	S D	Number
German	195 9	198 4	48 6	200
French	185 7	191 0	50 4	300
Italian	180 9	179 8	52 3	200

different nations, that the evidence for national differences must be regarded as inconclusive" (page 34)

DISCUSSION

By using a nonverbal type of intelligence test, Klineberg avoided the difficulties inherent in the attempt to translate the same test with equal adequacy into several languages The performance type of test which he employed required little more than the clear translation of the instructions for the subjects However, whether the tests were equally valid as tests of "native" intelligence for the several groups investigated is not altogether clear If they were valid tests of "native" intelligence, one would have to conclude from Klineberg's results that the urban children were superior in intellectual endowment to the rural children of this study

One possible explanation for such a superiority in the intelligence of urban children is suggested by Klineberg It may be that intellectually superior people are more likely than are the intellectually inferior to find or to make a superior environment for themselves and

their children, to strive for better schools and homes, and for the achievement of such ends to seek residence in urban and industrial areas Insofar as one is impressed by this argument, he will be inclined to attribute the city-country differences, at least in part, to differences in the intellectual capacity of the ancestors of the subjects, and thus in the "native" intelligence of the children themselves

An alternative explanation for the superiority of the scores of the urban children is that performance on these tests reflects not only native intelligence but environmental background as well In general, the living conditions of the groups which received high scores were superior to those of the low-scoring groups There was less poverty in the environments of the former groups, their means of communication were superior, their schools were better (by such indexes as discipline, attendance, educational methods, expenditures, etc) Moreover it is highly probable that in tests of the kind used in this investigation, city children, as compared with country children, enjoy an advantage from the general emphasis which is placed upon a competitive attitude and speedy performance in industrial communities and from their greater ease in the presence of strangers (here, specifically, the foreign experimenter) It may be that factors of this sort are responsible for the finding in this investigation, as in many others, that the average intelligence-test scores of urban children are higher than those of rural Klineberg himself believes that cultural-environmental differences between the country and city samples offer an adequate explanation for the difference in their average test scores

Klineberg's method of selecting representatives of the various "racial" and national groups to be compared eliminated certain ambiguities which other investigations of this question had presented For example, prior to the publication of Klineberg's study, a number of investigations had been carried out, comparing the average intelligence-test scores (1) of native Americans and of various groups of foreign-born Americans (*e g* , French, Jewish, German, Armenian, etc),[1] or (2) of the children of native Americans and of the children of

[1] The most comprehensive survey of the intelligence of immigrant groups resident in the United States was made by the Army testers during the First World War (Brigham, C *A Study of American Intelligence* Princeton, N J , Princeton University Press, 1923) A few years after the publication of this study, Brigham completely repudiated the conclusion that it had disclosed true differences, biologically based, in the intelligence of various national and "racial" groups among immigrants in the United

various groups of foreign-born immigrants In most of these studies differences, sometimes sizable, sometimes small, were reported in the average scores of the various groups compared Where differences were found, certain writers did not hesitate to infer that the various European national groups from which these samples came differ in intelligence in much the same way that their representatives in the United States were found to differ Apart from the fact that nationality is a legal characteristic, not a physiological or a psychological one, this inference may be challenged on two grounds First, it is possible that various uncontrolled factors, such as differences in motivation, in cultural level, in social and economic status, in educational attainment, and in language facility, may be responsible for such differences as have been found in the average intelligence-test scores of the various samples In the second place, even if the tests were equally fair to all the groups examined in the United States, it could not be assumed that the different groups of immigrants were *representative* samplings of their parent populations in Europe People emigrate from their homelands for many and very different reasons For example, they may emigrate because they are economic failures and therefore unable to survive at home, or, on the contrary, because they are economically successful and therefore have the means to reside in any country they choose As Klineberg says, "If for example the Scandinavians who migrated were a superior group compared with those who stayed behind, while among the Italians it was an inferior group which migrated, the conclusion that the parent populations differed in the same way as did the respective immigrant groups in America would hardly be justified ' (page 8) From this discussion it should be clear that no valid generalizations as to national or "racial" differences in intelligence can be based upon studies of immigrants or of the offspring of immigrants in the United States or elsewhere Whatever the findings of such studies, there will always remain the doubt as to whether the

States In this later evaluation of the results of the Army study, he wrote "Comparative studies of various national and racial groups may not be made with existing tests ," and " one of the most pretentious of these comparative racial studies—the writer's own—was without foundation " (Brigham, C Intelligence Tests of Immigrant Groups *Psychological Review*, 1930 vol 37, pp 158-165)

At the present writing no official publication has appeared which presents an analysis in terms of national or racial background of the psychological-test scores made by men in the armed services of the United States during the Second World War

particular immigrant sample tested was truly representative of the parent population

Klineberg avoided the pitfall inherent in the use of the questionably representative immigrant sample by two devices (1) by testing French, Italian, and German boys in their own countries, and (2) by selecting subjects with the physical traits which characterize the "Mediterranean," the "Alpine," and the "Nordic types" living in regions where those types are most commonly found His findings may therefore be taken as constituting significant evidence on the question of the existence of national or "racial" differences in intelligence

So far as *national* differences in intelligence are concerned, Klineberg found a slight superiority of French urban over Italian and German urban groups, and a somewhat greater superiority of the German rural group over the rural groups of the other countries These differences were much smaller than the differences between the rural and urban groups within each nation They are probably to be explained in terms of differences in cultural-environmental background factors

With regard to racial differences in intelligence, the results for the "Mediterranean," the "Alpine," and the "Nordic" samples warrant the conclusion that no significant differences in intelligence exist among the identifiable members of these three so-called "races"

CHAPTER XV

THE CONDITIONING OF VASOMOTOR RESPONSES

INTRODUCTION

When attention is called to some social lapse and a blush comes to the cheek of the indiscreet person, people ordinarily say, "Oh, he is embarrassed," and accept that as an explanation of the blushing. It is obvious that calling attention to the *faux pas* has somehow caused the blush, yet why should this particular effect have been produced rather than some other? The special problem of the present chapter concerns the manner in which such reactions come under the control of particular kinds of stimuli and become established as significant aspects of an individual's behavior.

Blushing or paling of the facial skin is called an "involuntary" response, since most people cannot say or think, "I will cause my cheeks to blush" (or to pale) and directly bring about the reaction. In contrast, after some training early in life, the individual can say or think, "I will move my finger," and thereupon produce that movement. The latter response is called a "voluntary" reaction because it can be regularly produced by the thought of making it. However, one cannot classify responses as being intrinsically either voluntary or involuntary. The term "involuntary action" is typically applied to responses which are not usually subject to control by words or thoughts or by any other stimulation which the individual can produce "at will." But it is possible that almost any such response can be made subject to this voluntary control if the person has had the appropriate combination of experiences or the right kind of training. For instance, only the exceptional individual can think, "I will move my ear," and directly do so. But through appropriate training, a number of subjects in an experiment by Bair[1] learned to make that response a

[1] Bair, J. H. The Practice Curve. *Psychological Review Monograph Supplements*, 1903, No. 19.

'voluntary' action. Not only such normally involuntary skeletal-muscle responses, but smooth-muscle responses as well may become subject to a voluntary control which is effected through learning. This possibility raises many questions of psychological importance.

For example, some religious cults exploit the fact that thinking affects bodily activities and insist that this phenomenon proves the dominance of "mind" over "matter." Psychologists regard such an interpretation as both mystical and vague and raise the question whether such mysticism and vagueness cannot be replaced by a more lucid explanation. That thinking influences visceral activities is an indisputable fact, but the problem of showing how this influence is exerted is a difficult one.

Some tentative suggestions may be advanced on this point. Let us consider the case of a clerk who has frequently worried about losing his job and has repeatedly thought, "They're going to fire me and I can't help it." As is well known, worrying typically interferes with the normal functioning of the digestive organs. Hence the clerk soon develops digestive disturbances, and in time the mere mention of the boss's name may produce a digestive upset. In such cases, it is reasonable to suggest that, through experience, processes of a so-called "involuntary" nature have come under the control of various stimuli which originally could not elicit such responses. These new stimuli tend to become associated with the original cause of the anxiety and may be furnished by the environment (*e.g.*, mention of the boss's name by someone else) or through the individual's own activity (*e.g.*, thoughts such as, "He has it in for me!").

The possibility that certain environmental stimuli and also habitual activities, such as speaking and thinking, may acquire a specific control over visceral processes is of great importance for our understanding of the nature of the neuroses and their development in the individual. Many neurotic individuals seem to be able to produce "at will"—that is, whenever it suits their purposes—such reactions as heart attacks, vomiting, headaches, and other responses which are not ordinarily under voluntary control. Naturally the fact that such behavior is exceptional does not preclude the possibility that when better understood it may be accounted for in terms of established psychological theory, without invoking mystical or supernatural explanations.

For example, the arousal of contradictory motives, such as the duty

of staying at home with an aged parent versus a desire to go out for the evening, frequently causes behavior difficulties, including emotional disturbances with their accompanying physiological disorders. As the situation productive of conflict is repeatedly encountered, a habitually disturbed and unstable emotionalized behavior may develop, a condition which is commonly called "neurotic." At length, merely thinking about the difficulty and the restrictions upon one's activities which it entails may arouse any or all of the symptoms which at first appeared only in the situation itself. Much neurosis, according to this view, is basically a form of "habit sickness" in which both visceral processes and general behavior have come under the control of stimuli associated with some serious maladjustment.

The manner in which thinking and related types of behavior may lead to changes in the functioning of internal organs suggests to the psychologist that particular organic changes come to be elicited by particular stimuli as the result of learning. If a reaction which is quite involuntary in most individuals can be trained ("conditioned") in the laboratory to previously ineffective stimuli selected by the experimenter, phenomena of the type we have mentioned lose much of their mystery. The experiment to be described below represents a special investigation of this problem.

THE EXPERIMENT OF ROESSLER AND BROGDEN[1]

In two earlier experiments by Menzies[2, 3] vasomotor responses (changes in the diameter of small arterial blood vessels in the skin), in particular, vasoconstriction (decrease in the diameter of those vessels), were conditioned to various stimuli, including sounds, visual stimuli, and the whispering of a nonsense word by the subject. Menzies used vasomotor reactions primarily because he wished to study a truly "involuntary" activity. In addition, as we have seen, vasomotor responses are of interest in both normal and abnormal psychology. In everyday behavior, the flushing or paling of the skin, which indicates that vasomotor dilation or constriction has occurred, is a

[1] Adapted from Roessler, R. L., and W. J. Brogden. Conditioned Differentiation of Vasoconstriction to Subvocal Stimuli. *American Journal of Psychology*, 1943, vol. 56, pp. 78–86.

[2] Menzies, R. Conditioned Vasomotor Responses in Human Subjects. *Journal of Psychology*, 1937, vol. 4, pp. 75–120.

[3] Menzies, R. Further Studies of Conditioned Vasomotor Responses in Human Subjects. *Journal of Experimental Psychology*, 1941, vol. 29, pp. 457–482.

frequent and often a very noticeable response in emotionally excited individuals Under unusual behavior conditions, such as the neuroses, peculiar vasomotor reactions are not uncommon, a fact which also suggests the importance of this type of response in emotion

Like Menzies, Roessler and Brogden selected vasomotor responses for investigation because they are excellent examples of a normally involuntary activity A further reason for selecting them was that Menzies already had shown that they could be conditioned to various external and internal stimuli, and therefore they seemed to be a suitable form of behavior for a conditioning study of a more elaborate type The particular aim of the present investigation—aside from undertaking to test further how vasomotor responses are conditioned both to spoken words and to thoughts—was to establish a "conditioned differentiation" Specifically, it was to determine whether the response of vasoconstriction could be conditioned to the repetition by the subject of a particular nonsense syllable, either aloud or subvocally, and at the same time *not* be conditioned to the similar repetition of another, different nonsense syllable An example of conditioned differentiation in daily experience would be to turn pale in response to certain thoughts (*e g*, "That pain is coming on again"), but not to give this response to other thoughts (*e g*, "I believe I'm feeling better") Behavior of this nature occurs in many people However, the means by which it is acquired is usually quite unknown to the individual concerned It is of great psychological interest to find out whether vasomotor responses can become conditioned to certain verbal stimuli, but not to others, by regular laboratory procedures Achievement of this result would furnish highly convincing evidence of the validity of the proposition that an involuntary reaction, through learning, can come under the control of words and thoughts as effective stimuli

THE NEURAL CONTROL OF VASOMOTOR RESPONSES

Vasomotor reactions have two phases *vasoconstriction*, which as we have said is the decrease in the diameter of blood vessels, and *vasodilation*, which is the enlargement in diameter of those vessels Vasomotor changes may be produced by certain chemicals (*e g*, adrenin) in the blood, but our concern here is with their direct nervous control

The principal nervous control of vasomotor reactions is effected

through the autonomic nervous system. Vasoconstriction is brought about by impulses transmitted through the sympathetic division of the autonomic nervous system, which discharges nervous impulses to the visceral organs from centers (*i e*, ganglia) lying in a double series parallel to the middle region of the spinal cord (see Fig 30). Vasodilation is thought to be produced by impulses transmitted to the blood vessels by way of fibers of the parasympathetic or craniosacral division of the autonomic system. Most of the centers of this division are

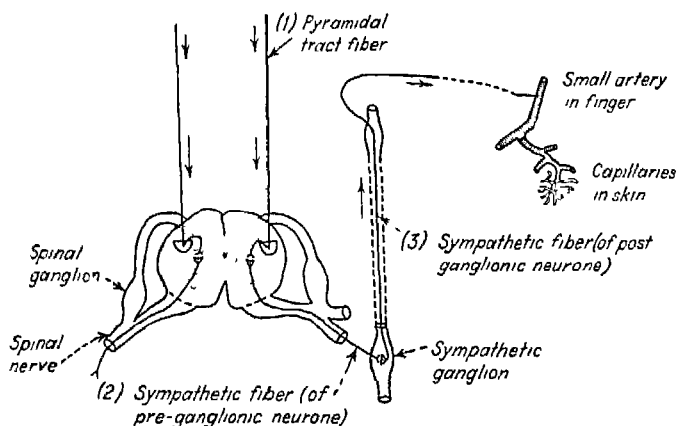



Fig 30 The Neural Control of Vasoconstriction, through the Sympathetic Division of the Autonomic Nervous System

Neural impulses from the brain (1) reach a level of the spinal cord in the thoracic region, then via preganglionic fibers of the sympathetic division (2) reach an adjacent sympathetic ganglion, and from the sympathetic chain are transmitted by a postganglionic fiber (3) to arterioles and capillaries in the skin, constricting these blood vessels. (The figure does not show the corresponding sympathetic ganglion on the other side of the spinal cord and the similar connections with the capillaries in the skin on the other side of the body.)

located in the medulla, though some are ganglia which lie in series parallel to the lowest (or sacral) region of the spinal cord.

APPARATUS AND EXPERIMENTAL SETTING

The experimenter chose vasoconstriction rather than vasodilation as the reaction to be conditioned. The US (unconditioned stimulus) was a high-voltage electric shock which, like many intense stimuli, would ordinarily be expected to produce vasoconstriction. The shock was delivered by electrodes strapped about 3 in. above the subject's left wrist. Since vasomotor responses which are aroused in the skin of one arm typically occur almost immediately in the skin of the other,

it was possible to use the subject's right arm to record and measure vasoconstriction produced by stimulation of the left arm In order to make the vasoconstriction easily measurable the blood vessels were kept in a state of dilation both by maintaining a high room

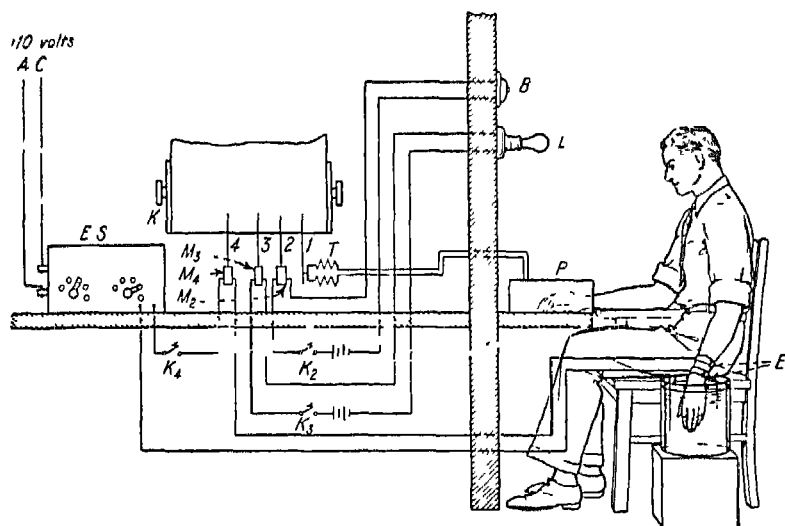



FIG 31 A Schematic Representation of the Apparatus Used by Roessler and Brogden to Investigate the Conditioning of Vasoconstriction Responses

P, plethysmograph, *B*, buzzer, *L*, lamp *E E*, electrodes attached to subject's left wrist, *K*, kymograph *ES* electrostimulator *T*, tambour M_2, M_3, M_4, signal magnets 1, stylus operated by tambour recording vasomotor changes 2, stylus recording auditory stimulus supplied by buzzer 3, stylus recording visual stimulation furnished by lamp, 4, stylus recording electrical stimulation K_2, key controlling buzzer, K_3 key controlling lamp K_4 key controlling stimulator

temperature (80°F) and by keeping the subject's left hand immersed in very warm water

The subject's right arm was strapped to an arm rest and fitted into an air plethysmograph[1] (see Fig 31) The plethysmograph was con-

[1] A plethysmograph is an instrument designed to measure changes in the volume of a limb which are caused by changes in the amount of blood in that limb In the more familiar type of plethysmograph, a cylindrical chamber is partly filled with water and the limb is suspended in it If the volume of the limb changes according to variations in the amount of blood contained, more or less water is displaced from the chamber, and the air volume and air pressure in the rest of the system change proportionately It is through changes in air pressure that the actual recording is done In the air plethysmograph the water is replaced entirely by air, and changes in blood volume bring about changes in air pressure directly

nected by glass tubing to an ink writing tambour, which recorded vasomotor changes on an electrically driven kymograph The operation of the buzzer, light, and electric shock used in the experimental procedure was also recorded on the kymograph All the recording equipment, as well as the apparatus by means of which the stimuli were presented, was located in a room next to the one in which the subject sat

METHOD

General Plan of the Experiment. The general plan of the experiment was to condition the response of vasoconstriction in the hands, first to the sound of a buzzer combined with the repetition aloud of a nonsense syllable by the subject, next to the same nonsense syllable repeated aloud by the subject but without the accompaniment of the buzzer, and then to the syllable repeated by the subject subvocally In addition, a conditioned differentiation was to be established That is, the subject was to be trained in such a way that the vasoconstriction would occur when he repeated the selected syllable, either aloud or subvocally, but would not occur when he repeated another and different syllable in similar fashion An electric shock to the left wrist served throughout as the US

Selection of the Subjects. The candidates originally chosen to serve as subjects for the experiment were 15 men, aged nineteen to twenty-two years, who were members of a class in elementary psychology at the University of Wisconsin

In order to become a subject in the experiment a candidate had to satisfy two requirements First, his initial (preexperimental) reaction to hand shock must be sufficiently reliable to provide a basis for the experiment When an electric shock was applied to his left wrist, he had to react with vasoconstriction in the right hand in at least four out of five trials Obviously, only subjects who reacted in this way would present a reaction which could be conditioned Second, it was necessary that at the outset the candidate not react characteristically with vasoconstriction to any of the conditioned stimuli used in the experiment, that is, he must not respond with significant frequency to the sound of the buzzer, or to either of the nonsense syllables, whether repeated aloud or subvocally The criterion of rejection of a candidate was a frequency of vasoconstriction to any

CS (conditioned stimulus) greater than one out of five trials If a candidate gave more frequent responses to any of these stimuli, it was considered probable that he had somehow been conditioned to them (or to stimuli like them) already, and thus had acquired the very associations which were to be established by the experimental training

In order to select individuals who could meet the above requirements, it was necessary to give a series of preliminary tests to the prospective subjects Six tests of this kind were given, in the order in which they are described below Each test consisted of five trials, that is, of five applications of the US, or of a given CS, or of some combination of conditioned stimuli The interval between trials was varied in random fashion Rest periods were introduced approximately every 25 min, their number and duration varying according to the subject's verbal expressions of fatigue A record of whatever vasomotor changes occurred was kept at every trial In each trial the experimental stimulus was not given until the vasodilation produced by the warm water and the high room temperature had reached its maximum As has been said before the purpose of securing a large initial vasodilation was to facilitate the measurement of any vasoconstriction that might occur later The latency and the magnitude of the vasoconstrictions were carefully measured "Latency" means the time in seconds for vasoconstriction to appear after the application of the stimulus "Magnitude" means the amount of decrease in the volume of the right hand in cubic centimeters, a measurement which was obtained from the decrease in air pressure in the plethysmograph when the hand volume diminished

In *Test* 1 the US, the electric shock, was given alone five times Each shock lasted 5 sec Nine of the fifteen candidates failed to give the response of vasoconstriction with sufficient frequency and so could not be used as subjects

In *Test* 2 the buzzer was the stimulus In each of the five trials it was sounded for 20 sec One of the remaining six candidates showed vasoconstriction too frequently to the buzzer and had to be eliminated

In *Test* 3 the candidate repeated the nonsense syllable "wek"[1]

[1] The experimenters used a nonsense syllable instead of an actual word in order to have a verbal reaction which would be equivalent to a spoken or a thought word but would be

aloud for 20 sec A flash of red light provided the signal for him to begin the repetitions, and another flash the signal to stop them One of the remaining five candidates responded too often with vasoconstriction to this stimulus and so was discarded

TABLE I

For Each of the Four Subjects, the Number of Vasoconstriction Responses to Shock (the US) in Test 1, the Average Latency (in seconds) and the Average Magnitude (in cubic centimeters) of the Responses Also, in Experiment I (Conditioning to Buzzer and "Wek" Spoken Aloud), the Number of Trials to Reach the Conditioning Criterion, and the Average Latency and Magnitude of the Conditioned Vasoconstriction Responses during the Five Criterion Trials[1]

	Subjects			
	A	B	C	D
Test 1				
No of vasoconstriction responses	4	4	5	4
Aver latency[2]	7 7	9 1	10 2	6 8
Aver magnitude[2]	0 12	0 20	0 16	0 29
Experiment I				
No of trials to reach the conditioning criterion (excluding the criterion trials)	15	55	20	20
Aver latency	5 1	6 1	5 3	7 0
Aver magnitude	0 06	0 07	0 06	0 06

[1] The "criterion trials" are the series of five successive trials during which the criterion of conditioning, to respond with vasoconstriction to the CS alone on at least four trials, was met

[2] In this and the subsequent table the figures indicating the variability of the latencies and of the magnitudes of the responses have been omitted

The four "surviving" candidates were given Tests 4, 5, and 6 In *Test* 4 the other nonsense syllable "zub" was repeated aloud under the same conditions and in the same manner as "wek" had been in Test 3 In *Test* 5 "wek" was repeated subvocally, also under the same conditions as in Test 3 Subvocal repetition meant that the subject was told to "think the word as actively as possible without whispering it or repeating it aloud" In *Test* 6 saying "wek" aloud was again used, this time in combination with the sounding of the buzzer for 20 sec In this test the beginning and the end of the

devoid of any special or direct past associations for the subject Since meaningful words already might have been associated with vasomotor changes in the subject, they were not suitable for use in an experiment of this type

buzzer sound served as the signals for the subject to start and stop repeating the syllable

All four individuals "passed" each of the above three tests and therefore became the subjects finally selected for the experiment The latencies and the magnitudes of their vasoconstriction responses to the electric shock in Test 1 are given in Table I

EXPERIMENTS AND RESULTS

In the experiment, each of the four subjects found suitable for the investigation went through two conditioning procedures, and two of the subjects went through five procedures These procedures will be designated as Experiments I, II, III, IV, and V, respectively

In all the experiments, the CS—whatever its nature might be—was 20 sec in duration In each trial the CS was presented first After it had gone on for 15 sec, the US (the electric shock) was given for a period of 5 sec Hence the CS and the US "overlapped," in that they were present simultaneously during the last 5 sec of stimulation The trials were given in series of five, with intervals of varying length between individual trials and between series of trials As in the preliminary tests, rest periods were introduced about every 25 min The criterion of conditioning was response by vasoconstriction to the CS alone in at least four out of five successive trials (*i e*, during one series) This response had to appear during the first 15 sec after the application of the CS, and before the reinforcement of shock occurred The criteria for the establishment of the conditioned differentiations in Experiments III and V are described below in connection with those experiments The five experiments were carried out in the same order for all the subjects As in the preliminary tests, the latency and the magnitude of each vasoconstriction were measured It follows from what has been said above that a vasoconstriction response could not be regarded as a CR (conditioned response) unless its latency was less than 15 sec

Experiment I. The aim of the first experiment was to condition vasoconstriction to the combined stimulation afforded by the sound of the buzzer and the simultaneous repetition of the syllable "wek" aloud by the subject As in all the experiments, the conditioned stimuli had a duration of 20 sec, that is, the buzzer sounded and the subject repeated "wek" for that length of time As we have said,

the shock was given after this stimulation had gone on for 15 sec., and continued during the last 5 sec of combined buzzer sound and repetition of "wek"

All four subjects were readily conditioned to respond with vasoconstriction to this stimulus combination As shown in Table I, the number of trials for conditioning the respective subjects to the criterion stated was 15, 55, 20, and 20 For three of the four subjects the average latency of the CRs was less than that of the unconditioned responses obtained in Test 1 In other words, vasoconstriction tended to appear more quickly after the presentation of the conditioned stimuli in this experiment than it had appeared in response to the electric shock given alone However, the vasoconstriction reactions to the new stimulus combination were on the average considerably less in magnitude than they had been in Test 1

Experiment II. The aim of Experiment II was to see whether vasoconstriction could be conditioned to "wek" alone, repeated aloud by the subject as before, but without the accompaniment of the buzzer At each trial a flash of red light was the signal for the subject to start saying "wek" The shock began 15 sec later, and its termination was the signal for him to stop repeating the syllable

As Table II shows, two of the subjects were conditioned in 25 and 5 trials, respectively The latencies and the magnitudes of their CRs were not very different from those of the CRs obtained in Experiment I The other two subjects, though they gave some evidence of conditioning, had not satisfied the criterion after 110 and 70 trials, respectively Since they also had failed to show any improvement with respect to the number of CRs per series, their training was discontinued and they were not used in the remaining experiments

Experiment III. The aim in Experiment III was to develop a *conditioned differentiation*, that is, to find whether the subject could be made to react with vasoconstriction to the syllable "wek" repeated aloud but not give this response to the syllable "zub," also repeated aloud The procedure was to alternate series of five presentations of "wek" reinforced (*i e*, followed) each time by shock, with series of five presentations of "zub" without shock reinforcement "Presentation" here means repetition of the syllable by the subject for 20 sec The alternation of the two kinds of series continued until the subject reacted with vasoconstriction to "wek" in four out of five successive trials, and did not react with vasoconstriction to "zub" in more than

one out of five successive trials The flash of red light was the signal for the subject to repeat either "wek" or "zub" The signal to stop repeating "wek" was the end of the shock (as in Experiment II), the signal to stop repeating "zub" was a second flash of the light

TABLE II

For Subjects A and D, in Experiments II, III, IV and V, the Number of Trials to Reach the Conditioning Criterion, together with the Average Latency (in seconds) and the Average Magnitude (in cubic centimeters) of the Conditioned Vasoconstriction Responses during the Five Criterion Trials

	Subjects	
	A	D
Experiment II Conditioning to "wek" aloud		
No of trials for conditioning	25	5
Aver latency	7 0	6 6
Aver magnitude	0 07	0 15
Experiment III Conditioned differentiation to "wek" and "zub" aloud		
No of trials for the differentiation, with "wek"	0	25
No of trials for the differentiation, with "zub"	0	30
Aver latency, CRs to "wek"	7 0	3 2
Aver magnitude, CRs to "wek"	0 07	0 63
Experiment IV Conditioning to "wek" subvocal		
No of trials for conditioning	5	25
Aver latency	3 5	5 0
Aver magnitude	0 11	0 67
Experiment V Conditioned differentiation to "wek" and "zub" subvocal		
No of trials for the differentiation, with "wek"	0	0
No of trials for the differentiation, with "zub"	0	0
Aver latency, CRs to "wek"	3 5	5 0
Aver magnitude, CRs to "wek"	0 11	0 67

As is shown in Table II, one of the two subjects (A) achieved the differentiation immediately, that is, he reacted with vasoconstriction at each of the first five trials with "wek" and reacted only once with vasoconstriction during the first five trials with "zub" The other subject (D) required 25 trials with "wek" and 30 trials with "zub" before the differentiation was regarded as established For subject A the average latency and magnitude of the CRs were similar to those previously obtained With subject D, however, the CR tended to be

given with more rapidly (*i e*, with shorter latency) than before, and with much greater magnitude

Experiment IV In Experiment IV vasoconstriction was conditioned to "wek" repeated subvocally, in "thought" The procedure was exactly the same as in Experiment II except that the subject repeated the syllable "to himself" instead of aloud

The conditioning was established rapidly in both subjects (see Table II), one subject requiring 5 trials, the other 25 For subject A the average latency of the CRs was less, and the average magnitude greater, than in any previous experiment For subject D the latency did not differ greatly from speeds obtained in the previous experiments, but the magnitude was slightly greater even than it had been in Experiment III

Experiment V. The purpose of this last experiment was to develop another conditioned differentiation, in this case between the two syllables repeated subvocally instead of aloud The procedure was exactly the same as in Experiment III except for the difference in the manner of repeating the syllables Both subjects exhibited the differentiation in the first series with each syllable and therefore required no additional training The average latency and magnitude of their CRs were identical with those in Experiment IV

DISCUSSION

These experiments by Roessler and Brogden, like the earlier work of Menzies, establish the fact that, through training, a vasomotor response of constriction may come to be evoked by a particular verbal stimulus, spoken aloud or merely "thought" They also show that a conditioned differentiation can be established, so that a subject may come to react with vasoconstriction to the repetition of a given word or thought but not give that response to the repetition of another word or thought For the most part the CRs were not difficult to develop Furthermore, as the training went on, there was a tendency for new conditionings to be acquired with increasing rapidity, and for the CRs to diminish in latency and to increase in magnitude It is noteworthy that once a conditioned differentiation had been developed to the two syllables repeated aloud, it "transferred" or carried over immediately to the same syllables repeated subvocally, so that no specific training with the two "thoughts" was necessary

The results suggest that in everyday experience the paling (and

presumably the flushing also) of a part of the face when significant words are heard may well be a CR established as a consequence of specific past "training" The findings also indicate the possibility that if one repeatedly says or thinks certain embarrassing or disquieting words when vasoconstriction (or vasodilation) occurs in connection with some general emotional condition, paling (or flushing) of the face may become a direct and specific response to the words in question Accordingly, it is clear that an important reason why a person's color "comes and goes" in the course of an ordinary conversation or argument may be that his vasomotor responses have become conditioned to different verbal stimuli in the course of his past experience

Individuals differ widely in their vasomotor responses in ordinary social situations Some people pale (or blush) intensely and often, others slightly and infrequently Some people blush most easily when they say or think profane or obscene words, others when they are talking or thinking about personal failures and humiliations For this reason one would expect to find rather wide individual differences in laboratory tests of vasomotor responses and in the acquisition of vasomotor conditionings The outcome of the present experiments confirms this expectation Most of the 15 men originally chosen as possible subjects did not respond consistently with vasoconstriction to an electric shock, although six of them did so respond Among these six individuals, only two reacted originally with vasoconstriction to a buzzer sound or to the repetition of a nonsense syllable, the others had to be specifically conditioned to one or the other of these stimuli Similarly, vasoconstriction in two subjects was conditioned successfully to a syllable repeated aloud, but in the other two this conditioning did not occur Although the causes of such individual differences are not known with certainty, they may include such factors as physiological differences in the ease with which vasomotor responses can be elicited, the effects of possible previous conditionings (including inhibitory ones), and the attitude of the subject during the experiment itself [1]

The results of Roessler and Brogden also show how so-called "involuntary" activities may be brought, through training, under the

[1] The results of Razran, among others, suggest that whether the attitude of a subject during an experiment is acquiescent, indifferent, or negative (*e g* , hostile) may determine whether or not a CR is established (Razran, G H S Conditioned Responses, an Experimental Study and a Theoretical Analysis *Archives of Psychology*, 1935, No 191.)

control of the individual's talking and thinking, that is, how involuntary responses may become "voluntary." Among other evidence for this statement is the fact that in Hudgins'[1] experiment the pupillary responses, both dilation and constriction, were separately conditioned to specific verbal stimuli, and that in Menzies' first experiment[2] vasoconstriction was conditioned to the whispering of a nonsense word. Such findings have great psychological significance, especially in the abnormal field. They suggest that in many abnormal individuals (e.g., cases of hysteria and neurasthenia) the appearance of symptoms such as nausea, "nervous indigestion," fainting spells, and the like may be attributed to conditioning in connection with the repetition of certain emotional difficulties. For instance, many neurotics are able to bring on a headache when particular disturbing conditions arise. An example is the case of a mother whose "illness" has long prevented her son from marrying, pleading "One of my headaches has come on" when the son announces his intention of taking a girl out to dinner or brings up the subject of a home and family.

The fact that such behavior can be viewed as a learned response-process becomes more clear when we consider some features of the headache. Headache characteristically involves marked changes in brain circulation, and extreme vasomotor changes in the thick capillary network of the cerebral cortex appear to underlie the typical "heavy" pain. Such vasomotor changes are apparently subject to conditioning, judging from the manner in which many adults develop or recover from headaches in connection with specific types of stimulation. Just as subjects in the present experiments and in Menzies' investigations acquired the ability to give a specific vasomotor response to particular stimuli, the headache of the neurotic—and of many "normal" people also—may be regarded as a special learned response to the special stimulus situations which evoke it. At first, the headache may be only an incidental consequence of the individual's general disturbance when he is confronted with an emotional crisis (which functions as the US). But if this crisis is encountered often enough, if the individual has enough experiences in which the stimuli producing the emotional disturbance are followed by headache among other effects, the vasomotor changes which underlie the pain may come to be elicited

[1] Hudgins, C. V. Conditioning and the Voluntary Control of the Pupillary Reflex. *Journal of General Psychology*, 1933, vol. 8, pp. 3-51.

[2] Menzies, Conditioned Vasomotor Responses in Human Subjects.

by one particular stimulus alone The individual who says, "Don't mention his name, or I'll have one of my headaches!" thereby discloses a CR which has a person's name as a CS, and the fact that the headache does not occur as a response to the names of other people reveals the existence of a conditioned differentiation Such special habits persist and become stronger by virtue of the fact that they often help the individual to avoid or to escape from situations which he finds disturbing

On the other hand, if the outcome of the experiments of Roessler and Brogden affords an explanation for the establishment of many neurotic symptoms, their results also suggest how special procedures for the removal of such difficulties may be devised If an individual can learn to react with vasoconstriction to a particular stimulus by repeatedly pairing that stimulus with some US for the response, it should be possible to recondition him, to train him to lose the conditioned vasoconstriction, by pairing the CS with some stimulus that produces a different response, *e g*, vasodilation

For this reconditioning in the case of headache the CS might be paired with any stimulus that tends to have a "calming" effect, that tends to bring about a general relaxation of the musculature and a vasomotor condition different from that which underlies the headache Such a stimulus might be listening to music, thinking of pleasant events in one's past, repeating a mystic formula such as "There is no pain," or listening to and later recalling the advice and encouragement of a psychiatrist or counselor If the pairing in question occurs repeatedly under the proper conditions (among which may be a genuine desire on the part of the patient to get rid of his headaches), the former CS, *e g*, the mention of a disliked person's name, may cease to produce pain In a similar manner, and in accordance with the same principle, various difficulties in individual behavior may be displaced by more desirable types of adjustment A method of the above type, together with several related procedures, is described and discussed in detail in Chap XIX [1]

[1] The above comments should not be interpreted as an attempt to oversimplify psychotherapy along behavioristic lines The reconditioning method suggested probably would be much more effective for eliminating a single localized symptom, such as a headache, than for alleviating a complex attitude, for example, a "feeling of inferiority" Also, though it is conceivable that a simple reconditioning might be effected without the active cooperation of the subject, it is very unlikely that it could be achieved against his actual opposition, whether the latter was openly displayed or existed more as an attitude of which he himself was perhaps unaware

CHAPTER XVI

FORGETTING DURING SLEEP AND WAKING

INTRODUCTION

Recently, several psychological experimenters have undertaken to compare the amount of forgetting which takes place during sleep and during waking. In reality, all such experiments are primarily studies of retroactive inhibition. This term may be defined as the inhibitory effect exerted upon the retention of any activity (or material) by other activities intervening between the original learning and the retention test. The existence of such inhibitory effects was first demonstrated by two German psychologists, Muller and Pilzecker,[1] in 1900, but the importance of their discovery was so little realized that for 24 years the topic was relatively neglected in experimental psychology.

In 1924, however, there appeared the study of Jenkins and Dallenbach which is reviewed in this chapter. The results of their experiment were so striking as to give a new impetus to work in this field. At present, the investigation of retroactive inhibition has become one of the principal experimental problems in the psychology of retention and memory. Moreover, the phenomenon itself has been widely recognized as one of the most important causes of forgetting and, consequently, as the cause of much of our habitual failure to remember accurately the things which we have learned.

THE EXPERIMENT OF JENKINS AND DALLENBACH[2]

PURPOSE

The purpose of the experiment of Jenkins and Dallenbach was "to compare the rate of forgetting during sleep and waking." Their specific incentive for undertaking this problem derived from their desire to account for certain unexplained discrepancies in some of the curves

[1] Muller, G. E. and A. Pilzecker. Experimentelle Beitrage zur Lehre vom Gedachtnis. *Zeitschrift fur Psychologie und Physiologie der Sinnesorgane*, Erganzungsband, 1, 1900.

[2] Adapted from Jenkins, J. G., and K. M. Dallenbach. Obliviscence during Sleep and Waking. *American Journal of Psychology*, 1924, vol. 35, pp. 605–612.

of forgetting reported by Ebbinghaus,[1] the pioneer in the experimental study of learning and memory In one case, for example, Ebbinghaus found three times as much forgetting after 24 hr as after 15 hr Why should an increase in the time between learning and recall amounting to only 9 hr, or 60 per cent, produce a 300 per cent increase in the amount forgotten? If forgetting goes on more rapidly during waking than during sleeping, this discrepancy could be explained For in Ebbinghaus's studies sleeping had filled a much larger proportion of many of the 15-hr intervals than it had of most of the 24-hr ones Ebbinghaus himself suggested this explanation but finally discarded it in favor of the assumption that the discrepancy was due to some kind of accidental error in his work Jenkins and Dallenbach, however, thought that his rejection of that explanation was premature, and decided to test the matter thoroughly themselves

This, then, was their particular purpose But the conclusions and implications which follow from their experiment go far beyond the relatively narrow aim set forth above

METHOD

Subjects The subjects were two senior college students Both were without experience in psychological experimentation and were wholly ignorant of the purpose of the investigation For the entire duration of the experiment they slept in an improvised room next to the laboratory, but otherwise they went about their daily affairs as usual[2]

Material Learned. The material to be learned was typewritten lists of nonsense syllables of the usual three-letter, consonant-vowel-consonant kind (*e g*, *baf, lum, sev*) Each list contained 10 syllables

Method of Learning. The syllables were shown to the subjects visually by means of a special exposure apparatus They were always shown in the same order Each syllable appeared separately for a period of 0 7 sec and the subject pronounced it aloud as soon as he saw it After every presentation of the list, he recited as many of the syllables as he could remember The list was then shown again,

[1] Ebbinghaus, H *Uber das Gedachtnis Untersuchungen zur experimentellen Psychologie*, pp 85–109, 1885

[2] It is worth noting that, although most psychological experiments employ many more than two subjects, it often happens that an intensive study of a few individuals gives just as valuable results as are obtainable from a less intensive study of a large number

and again he recited as much of it as he could This procedure was continued for each of the subjects until he could recite the entire list once from the beginning to end in correct order It was then considered to be learned The subject was told not to try to read any meaning into the syllables, and not to use any special plan (mnemonic device) for remembering them

Method of Measuring Retention. The subject's retention (*i e* , his memory for the list) was tested by the recall method, which means that after some prescribed interval of time he recited as much as he could remember of the list he had previously learned The lengths of these prescribed intervals were different on different occasions and for different lists Specifically, they were 1, 2, 4, or 8 hr after the learning

Activities between the Learning and the Retention Test. The crucial point in the experimental procedure was the difference in the kind of activities intervening between the original learning of a list and the later recall of it The lists were learned either between 11 30 P M and 1 A M , or between 8 and 10 A M (except for some sessions between 2 and 4 P M , introduced as an additional check) For the learning at night the subject undressed and got ready for bed before the learning started, and went to bed, and usually to sleep also, just as soon as it was over The daytime learning, however, occurred in the midst of and as a part of his normal waking activities Hence, the learning at night was followed by sleeping, *i e* , by a minimum of general activity, whereas the daytime learning was followed by the customary routine of study, attendance at lectures, eating, conversation, sports, and the like

With respect to the recall tests which were given after the 1- to 8-hr intervals mentioned above, the following procedure was employed If the learning was at night the subject was never told how soon he would be called upon to recite the list again Instead, he was awakened by the experimenter during the night at the appropriate time, or summoned by him early the next morning, to recall it The reason for not telling the subject beforehand after what interval his retention would be tested was based on the discovery that his attitude on going to sleep differed in accordance with whether he knew the interval before reproduction was to be short or long It was noted, incidentally, that during many of these night recalls the subject was scarcely awake

and that the next morning he often could remember nothing about having had to recite the syllables If the learning took place during the daytime, however, the subject was told to report back to the laboratory at a certain later hour for the recall In all cases, the subjects were told never to repeat the lists during the interval

Duration and Extent of the Experiment. The experiment lasted from April 14 to June 7 Records were taken on almost every day and night during that period, unless the subject's physical condition prevented Each subject learned eight lists for each of the four intervals, and for both the sleeping and the waking conditions The total number of lists learned and recalled by both subjects was 123 (there were five omissions in the above schedule)

RESULTS

The results of the experiment are shown for each subject individually in the following table and graph The average number of syllables recalled is given for all four intervals and for both sleeping and waking

TABLE I

Showing the Average Number of Syllables Recalled by Each Subject after from 1 to 8 Hr Spent in Sleep or in Waking Activities

Subjects	Intervals								Average for all intervals	
	1 hr		2 hr		4 hr		8 hr			
	Sleep	Waking	Sleep	Waking	Sleep	Waking	Sleep	Waking	Sleep	Waking
H	7 1	4 4	5 4	2 8	5 3	2 4	5 5	0 4	5 8	2 4
Mc	7 0	4 8	5 4	3 4	5 8	2 1	5 8	1 4	6 0	2 8

conditions Ten syllables, it will be remembered, were learned in every one of the lists Hence, a recall score of seven syllables, for example, shows that 70 per cent of the list originally learned was recalled or, conversely, that 30 per cent of the list was forgotten

The results show very clearly that for both subjects retention after an interval during which the subject was asleep was far superior to retention after an equivalent interval during which he was engaged in his normal waking activities For example, subject H after a 2-hr interval spent in sleep recalled 5 4 syllables, but after 2 hr occupied

with waking activities, he recalled only 2.8 syllables—scarcely more than half as many. This difference in favor of the sleep condition was found to be present for all of the intervals used. Furthermore, the magnitude of the difference increased as the intervals became longer.

As the graph in Fig. 32 also shows, there seemed to be no decline in recall ability during the sleep condition after the 2-hr. interval, for the subjects recalled as many syllables after 8 hr. as they did after 2 hr. Under the waking condition, however, the recall score steadily decreased as the interval grew greater, so that the recall after 8 hr. was much less than it was after 2 or 4 hr. In fact, after the 8-hr. interval,

FIG. 32. Retention after Sleep and after Waking

the retention had diminished to scarcely 10 per cent of the list originally learned, *i.e.*, 90 per cent of the syllables had been forgotten.

The experiment was repeated with one other subject, for the 1- and 8-hr. intervals only, with results virtually identical with those reported above.

One question which might be raised is whether there was any difference in the difficulty of learning the lists under the night and the daytime conditions. On the average, there was a difference, namely, that the night learning usually required from one to two more repetitions of a list than did the day learning. However, this difference was not always present, nor was it found in the third subject mentioned above. It is very unlikely, therefore, that it had any significant effect on the later retention.

CONCLUSIONS

The authors of the experiment conclude that, as their results clearly indicate, forgetting goes on at a slower rate during sleeping than it does during waking. Insofar as the discrepancies in Ebbinghaus's data are concerned, Jenkins and Dallenbach conclude that they were due simply to the fact that certain of his intervals (*e g*, the 15-hr ones) tended to include more sleeping time than others did.

DISCUSSION

As we have seen, Jenkins and Dallenbach found that retention after sleep was far superior to retention after waking activities, when the time intervals between the learning and the recall test were identical. Five other experimenters also have compared retention after sleep and after waking and have obtained essentially similar results.[1] The most probable explanation of these findings is that during sleep almost all the activities of the organism are at a minimum, so that fewer reactions occur of a sort that might interfere with or inhibit the recall of what was originally learned. During normal waking activity, however, the number and variety of the responses which an individual makes are enormously increased. Hence, many reactions which can interfere with recall are almost certain to occur, even if the interval between learning and recall is as short as 1 hr.

As we have already said, this interference with the recall of something learned by activities occurring between the learning and the retention test is called "retroactive inhibition," and retroactive inhibition is now generally believed to be one of the principal causes of forgetting. Inability to remember something is not due to the mere lapse of time. If it were, then after any given period, *e g*, of 4 hr, one should remember just as much as he would after any other period of identical length. But this is precisely what did *not* happen in the experiment of Jenkins and Dallenbach. Their study showed that, in actuality, the nature of an individual's activities during a given interval greatly influenced his ability to recall what he had learned.

If retroactive inhibition is so important as a cause of forgetting one

[1] Three of these experiments are the following: Van Ormer, E B, Retention after Intervals of Sleep and Waking, *Archives of Psychology*, 1932, No 137; Graves, E A, The Effect of Sleep upon Retention, *Journal of Experimental Psychology*, 1936, vol 19, pp 316–322; Newman, E B, Forgetting of Meaningful Material during Sleep and Waking, *American Journal of Psychology*, 1939, vol 52, pp 65–71.

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As we have already said, this interference with the recall of something learned by activities occurring between the learning and the retention test is called "retroactive inhibition," and retroactive inhibition is now generally believed to be one of the principal causes of forgetting Inability to remember something is not due to the mere lapse of time If it were, then after any given period, *e g* , of 4 hr , one should re member just as much as he would after any other period of identical length But this is precisely what did *not* happen in the experiment of Jenkins and Dallenbach Their study showed that, in actuality, the nature of an individual's activities during a given interval greatly influenced his ability to recall what he had learned

If retroactive inhibition is so important as a cause of forgetting one

[1] Three of these experiments are the following Van Ormer, E B Retention after Intervals of Sleep and Waking *Archives of Psychology*, 1932, No 137, Graves, E A The Effect of Sleep upon Retention *Journal of Experimental Psychology*, 1936, vol 19, pp 316–322, Newman, E B Forgetting of Meaningful Material during Sleep and Waking *American Journal of Psychology*, 1939, vol 52, pp 65–71

might inquire why anything at all was forgotten during the sleeping state in these experiments. To such a question two answers are possible: (1) Retroactive inhibition is not the only cause of forgetting; (2) even in the sleep condition some activity is present. In the study of Jenkins and Dallenbach, the subject did not always go to sleep the instant the learning was completed, and even during sleep numerous reactions undoubtedly occurred, such as various postural adjustments and dreaming. It is possible, too, that the retention of what had been learned was interfered with to some extent by the continuing vegetative activities of the body, such as respiration, circulation, and digestion.

In connection with the effect of sleep upon retention, the experiment of Newman[1] reveals a point of special interest. In this investigation the subjects learned "sense material" (specifically short stories of about three-hundred words each), instead of nonsense syllables, word pairs, and the like which had been used in all the earlier studies.

Each story was so constructed that it contained 12 items that were essential to the general meaning of the narrative, and 12 that were nonessential. The stories were read by the subjects in the morning, in the afternoon, or at night, and recall was required 8 hr. after the reading. Although recall was superior when the learning occurred at night and therefore was followed by sleep, the superiority of the night condition was pronounced only for the reproduction of the nonessential items. For the recall of the essential items, the night condition was only slightly more effective. Such a result is readily understandable. In general, material that is more meaningful, more related and organized, is better retained, *i.e.*, is less likely to be forgotten (see Chap. XVIII). One of the principal causes of forgetting is retroactive inhibition. Since meaningful material is less apt to be forgotten than nonsense material, it is presumably less susceptible to retroactive inhibition (*i.e.*, is more resistant to interference), at least from the various daily activities in which most persons are engaged. If the susceptibility of sense material to retroactive inhibition from daily waking activities is relatively small, it follows that the removal of such inhibition, by the substitution of sleep for waking during the intervals between learning and recall, would improve retention very little compared with the effect that would be expected if the material were of the nonsense

[1] Newman, *op. cit.*

type In this way one can explain the very small superiority of the sleep condition which Newman found for the recall of the essential items in his stories, as well as its marked superiority for the recall of the nonessential items

The explanation of retroactive inhibition that is, the explanation of how activities which occur after learning can interfere with later recall of the material learned, is still a question of great interest to psychologists Likewise, such problems as the variation of retroactive effect with differences in the nature of the activities learned in the degree to which the activities are practiced, etc , occupy the attention of many investigators in the field of retention and memory However, all of these topics lie beyond the scope of the experiment of Jenkins and Dallenbach and, except for the results of Newman cited above, beyond the scope of the present chapter as well

CHAPTER XVII

THE EFFECT OF OVERLEARNING UPON RETENTION

Introduction

Among the important problems in the general field of learning and memory is the effect of overlearning upon retention. By "overlearning" is meant practicing an act to an extent greater than that necessary just to learn it. For example, if the act were memorizing a list of words, overlearning would mean going over the list more times than was necessary to repeat it just once correctly.

In general, everyone would agree that the more one practices anything, provided he works at it attentively and purposefully, the better he will be able to recall it later. Yet this, like many plausible notions in the field of psychology, must be experimentally demonstrated before it can be accepted as true. Furthermore, even if overlearning does usually result in improved retention, it is not certain just how great the benefits derived from different amounts of overlearning will be. Suppose it takes 10 repetitions to learn a list of words, which are to be recalled a week later. If the subject after learning the list had practiced it five times more, which would mean giving it 50 per cent more repetitions, would he remember 50 per cent more of it? Or, if he had given the list 10 additional repetitions, making 20 in all, would his recall be 100 per cent better? Likewise, the value of a given amount of overlearning might not be the same after different intervals had elapsed between the original learning and the retention test. If, for example, 50 per cent overlearning increased one's retention 60 per cent on a test given one day later, would its value be greater or less if the interval had been, say, four weeks instead of one day only?

For questions like these, common sense can give no clear answer. The last two problems, in particular, are of considerable practical significance, but they can be solved only by the carefully controlled experimentation which is exemplified in the studies reviewed in this chapter.

I KRUEGER'S EXPERIMENT WITH WORD LISTS[1]

PURPOSE

The purpose of Krueger's experiment was to determine the effect of different amounts of overlearning upon the retention of lists of words after various prescribed intervals of time

METHOD

Subjects Twenty subjects were used in the experiment (Presumably these were college students, although Krueger does not so state)

Material Learned. The material to be learned was made up of lists of 12 nouns, each having one syllable only (*e g*, barn, lamp, tree, chair)

Method of Learning. Each list of nouns was shown visually, in a series, and always in the same order, each word was visible for 2 sec The method of learning employed was the so-called "anticipation" method, a procedure which permits a high degree of control of the subject's behavior This method requires that the subject try to "anticipate" each word in the list by saying it aloud when he sees the word which comes just before it in the series The first time the list is presented to him he, of course, cannot do this, since all the words are strange to him During this first trial, therefore, he simply looks at and pronounces each word as it appears But on all later trials he tries to anticipate by giving the second word in the series when the first word appears, the third word when the second appears, etc That is, he endeavors to make each successive word as it is presented to him a cue or stimulus for pronouncing the next word in the list Krueger's method conformed to the above description, except that it was only on every other trial that the subject actually tried to "anticipate" On alternate trials, he merely observed the words as they appeared

A list was considered just learned when the subject could go through it once without error, that is, when he could correctly anticipate all the words in it during a single presentation

The Overlearning. The degree of proficiency represented by one successful anticipation of the entire list during a single exposure

[1] Adapted from Krueger, W C F The Effect of Overlearning on Retention *Journal of Experimental Psychology*, 1929, vol 12, pp 71–78

Krueger called "100 per cent learning." Any practice beyond the amount necessary to achieve this result would then be overlearning. Krueger employed two degrees of overlearning, which he designated as 150 per cent learning and 200 per cent learning. In the former, the subject, after he had been given enough trials to learn the list according to the above standard, was given 50 per cent more trials. That is, if he had required 10 repetitions for the 100 per cent learning, he would now be given five overlearning trials. In the 200 per cent learning he was given 100 per cent more trials than were necessary to learn the list. Hence, if he had needed 10 trials to learn it, he would now be given 10 overlearning trials, making a total of twice as many as had been required just for learning.

The Retention Tests. The test of retention was given at a prescribed interval after the learning was finished. Six different intervals were used, 1, 2, 4, 7, 14, and 28 days. No list was tested for recall more than once; hence, if the interval was 14 days, the list recalled then would always be one which had never been tested at any previous time.

Each retention test was twofold in nature. First, the subject went through the list once by the same anticipation method that had been used for the learning, and the number of his correct anticipations was recorded. The number of words thus correctly anticipated, and the per cent which that number was of the 12 words originally learned, constituted the subject's *recall score*. (The recall scores are given in columns 3 and 4 of Table I.) Following this, the subject was given a sufficient number of presentations of the list for him to relearn it to the 100 per cent standard, *i.e.*, to anticipate correctly every word in it during one single exposure. The number of trials required for this relearning was then compared with the number necessary for the original learning. On the basis of this comparison the retention in per cent saved, called the *saving score*, was computed. The formula for this calculation is

$$\text{Per cent saved} = \left(1 - \frac{\text{number of trials for relearning}}{\text{number of trials for learning}}\right) \times 100$$

If a subject required 10 trials to learn a list originally and 4 trials to relearn it a week later, the per cent saved would be $(1 - 4/10) \times 100$, or 60. In other words, he retained what he had learned sufficiently

well to require 60 per cent fewer repetitions to learn the same material once more (The saving scores are given in column 5 of Table I)

It should be noted that these two methods of testing retention measure different aspects of it The recall method takes account only of those responses which the subject can make without any additional practice with the material The saving method, however, gives weight to any traces of the effects of the original learning which, though insufficient to make complete recall of a response possible, are still sufficient to make relearning of it easier As one would expect, the per cent retained is in most cases greater by the saving method

Amount of Data Obtained As Table I shows, there were six retention intervals and three degrees of learning (of which two were degrees of overlearning) for each interval Hence in all there were 18 different conditions Different groups of subjects were used for the different intervals, but the same group was tested for all of the three different degrees of learning for any one interval Every subject learned a different list of approximately equal difficulty for each of his learning-retention records, but different subjects could, of course, use the same lists The total number of lists learned, and so the total number of individual retention scores obtained, was 20 for each of the 18 experimental conditions, except that there were 40 for each of the three degrees of learning at the one-day interval

RESULTS

Krueger's findings are presented in Table I For the most part, the results given below are very clear-cut, and statistical treatment shows that practically all of the differences between the various retention scores are highly reliable [1]

150 Per Cent versus 100 Per Cent Learning Comparison of 150 and 100 per cent learning (*i e*, 50 per cent overlearning and bare learning) shows that in all cases the former was superior, since the retention score was higher for every interval and by both methods of measuring retention Furthermore, it is evident that 50 per cent additional practice was in every sense worth while, since it always gave at least 50 per cent better retention, and in most cases produced an increase far exceeding that figure After seven days, for example, it produced a recall score more than six times higher than the score for

[1] See Chap I, p. 9 for an explanation of the reliability of differences

100 per cent learning and a saving score more than 13 times higher. As for the relation between the value of 50 per cent overlearning and the length of the time interval, it is clear that as the interval increased in length the value of the overlearning increased also. For example

TABLE I

The Average Number of Words Recalled, the Average Percentage of the Original List Recalled, and the Average Per Cent Saved, for Each of the Three Degrees of Learning after Each of the Six Intervals[1]

Length of interval, days	Degree of learning (per cent)	Average number of words recalled	Average per cent of the list recalled	Average per cent saved
1	100	3.10	25.83	21.73
	150	4.60	38.33	36.15
	200	5.83	48.58	47.10
2	100	1.80	15.00	13.40
	150	3.60	30.00	33.45
	200	4.65	38.75	42.05
4	100	0.50	4.17	3.40
	150	2.05	17.08	29.75
	200	3.30	27.50	32.30
7	100	0.20	1.67	1.75
	150	1.30	10.83	23.15
	200	1.65	13.75	27.55
14	100	0.15	1.25	1.65
	150	0.65	5.42	20.80
	200	0.90	7.50	25.45
28	100	0.00	0.00	1.70
	150	0.25	2.08	20.50
	200	0.40	3.33	25.10

[1] The average number of trials required for the original learning varied between 4.15 and 4.85 repetitions for the different lists. Since the variation was so small, the lists must have been approximately equal in difficulty.

after a one-day interval, 50 per cent overlearning was 67 per cent superior to 100 per cent learning by the saving method, after 2 days, it was nearly 250 per cent superior, and after 28 days, over 1,200 per cent.

200 Per Cent versus 150 Per Cent Learning. Comparing 200 and 150 per cent learning (*i e*, 100 per cent and 50 per cent overlearning), however, one obtains a somewhat different picture from that afforded by the comparison above To be sure, 200 per cent learning gave the higher score at every interval by both the recall and the saving method But since 200 per cent learning requires one-third (or 33 1/3 per cent) more repetitions than does 150 per cent learning, to prove itself *proportionately* superior to the latter it must give 33 1/3 per cent better retention Inspection of the table shows that for the most part it did not have this value By the recall method, 200 per cent learning was a little more than one-third superior to 150 per cent learning at three of the intervals, but less than one-third superior at the other three By the saving method, it did not produce as much as 33 1/3 per cent better retention at any interval whatever As for its value at different intervals, no consistent relationship was shown, by the saving method, it was 30 per cent superior after 1 day, 19 per cent superior after 7 days, and 22 per cent superior after 28 days

CONCLUSIONS

Krueger draws the following conclusions from his data

1 As the degree of learning was increased from 100 per cent to 150 per cent, the corresponding increase in retention for the one-day interval was approximately the same, and this ratio increased rapidly as the length of the interval between learning and recall was extended

2 As the degree of learning was increased from 150 per cent to 200 per cent (that is by an additional 33 1/3 per cent), the corresponding increase in retention was usually less, and this proportion did not vary consistently with the length of the interval

A certain degree of overlearning, at least 50 per cent, is highly economical from the standpoint of retention for intervals of 2 to 28 days, and the larger the interval, the greater is the economy Further increases of overlearning, however, proved to be uneconomical for most intervals

To the reviewers, the results suggest that although any and all amounts of overlearning may be expected to have value in the sense that they will produce some degree of improvement in retention, it cannot be expected that the betterment will continue to be proportional to the amount of extra practice involved Diminishing returns are probably bound to show themselves sooner or later

II KRUEGER'S EXPERIMENT WITH MAZES[1]

Krueger subsequently repeated the entire experiment, using mazes instead of lists of words as the material for learning The same three degrees of learning (100 per cent, 150 per cent, and 200 per cent) were employed, and retention was tested after intervals of from 1 to 28 days The results of this second study were very similar to those of the first, except that with the mazes 150 per cent learning did not have quite its proportional value whereas, rather surprisingly, 200 per cent learning did That is, the retention value of 200 per cent learning of mazes was always at least 33⅓ per cent superior to the retention value of 150 per cent learning

Apparently for the purpose of finding whether with mazes, as well as with words, a sufficiently great amount of overlearning would produce diminishing returns, Krueger now had other subjects practice the mazes to the degree of 300 per cent learning That is, after a subject had practiced a maze enough to enable him to traverse it once without error, he was then given twice as many additional trials It was found that, although 300 per cent learning was superior to any smaller amount for all intervals, it was nevertheless not proportionately superior, *i e*, it was not so much as 50 per cent better than 200 per cent learning Hence, the principle of diminishing returns which held for words was demonstrated to be true for mazes also

Comparison of the two experiments shows, however, that the point at which the returns from overlearning begin to diminish is not the same with different activities and materials With the word lists that point seems to have been somewhere between 150 and 200 per cent learning, with the mazes it probably fell between 200 and 300 per cent learning

Discussion

The practical implications of Krueger's work are fairly obvious Practice beyond the amount necessary for just barely learning an activity may always be expected to improve one's retention of it to some extent (provided, that is, that the extra practice is carried out with proper attentiveness and with adequate motivation) However, no one can expect that this extra practice will continue to yield propor-

[1] Adapted from Krueger, W C F Further Studies in Overlearning *Journal of Experimental Psychology*, 1930, vol 13, pp 152-163

tionate returns The favorable effect of a little overlearning may be very great, but although very large amounts of overlearning will yield some further advantage, the gain may seem small in comparison with the additional time and effort expended At least this conclusion seems warranted for the types of material used in Krueger's investigations

This statement does not mean, however, that large amounts of overlearning are not worth while Whether they are or are not depends solely on how important perfect retention is to the individual If it is essential that his memory for some particular material be as accurate and reliable as he can possibly make it—which is the case, for example, when a pianist practices for a forthcoming concert—then, in spite of the principle of diminishing returns, very large amounts of overlearning will still be profitable to him For there is no reason to suppose that even the last 100 trials out of 10,000 would not add something, however small, to the excellence of his subsequent performance

Also it might be noted that the value of various amounts of overlearning for the retention of logically organized verbal material (such as a class assignment in psychology) may be different from the values found by Krueger for the retention of lists of unrelated words and of mazes In general, it is not safe to assume that the efficacy of a given method of learning will be the same for different kinds of material Such an assumption is especially insecure if the materials differ widely with respect to the complexity of their interrelationships and the nature of their organization [1] Unfortunately, however, no experiments dealing with the value of overlearning for the retention of logical verbal material have yet been performed

[1] See Chap XVIII for a discussion of the effect upon memory of organizing the material to be learned

CHAPTER XVIII

THE IMPORTANCE OF ORGANIZATION FOR RETENTION AND TRANSFER[1]

Introduction

One of the most important topics in the investigation of learning is the relation between the organization of the material or activity to be learned and the speed with which the activity is mastered, the degree to which it is retained, and the likelihood that transfer[2] to other situations will occur. Especially significant is the kind of organization which makes possible the development of a general principle, and the effect of such a principle—when acquired and understood by the learner—upon his retention of what he has learned and his ability to transfer it (or apply it) to a subsequent different situation.

Organization in its simplest form may be characterized as merely a sort of grouping. Thus, a subject who is trying to memorize the 12 digits 581215192226 may group them, say, by three's, and may therefore perceive and repeat the series as 581 215 192 226. If he says the series to himself he probably will employ rhythm also, perhaps accentuating the first of each group of three digits, either subvocally or aloud.

It has been demonstrated repeatedly that even organization of this kind, which Katona[3] terms "rudimentary . . . arbitrary and artificial," is superior to no organization at all, in that it leads to quicker learning of a series and to better and longer retention of it as well. Presumably the reason for its value is that it involves the establishment of relationships between the items of the material (here the different digits), and yields a kind of form, pattern, or "Gestalt" which confers some measure of unity upon the material. A series of 12 digits may become

[1] Based on Katona, George *Organizing and Memorizing* Copyright, 1940, by Columbia University Press, New York.

[2] "Transfer" or "transfer of training" means the influence of prior learning upon the learning of, or response to, new related material.

[3] Katona, *op cit*, p 18, see also his discussion on pp 165–192 and 283–287.

through rhythmic grouping a sequence of four groups of three digits each with the accent on the first digit of each group. The series now has more form, more pattern, than would be possessed by a 12 digit series in which each number was treated as separate and unrelated to any other.

There are many kinds and degrees of organization which may be employed in learning. Some of these are highly effective for the purposes of learning, retention, and transfer. Others by contrast are inadequate for such uses. In the above example the organization by arbitrary grouping is, as we have said, preferable to no organization at all. But it is very inefficient compared with the kind of organization which this particular number series permits. If the series is examined closely, it may be seen that the sequence of digits is by no means a chance one but proceeds according to a definite arithmetical principle. Actually the series is formed by beginning with the number 5, then adding alternately 3 and 4 to the last preceding number. Thus 5 plus 3 is 8, the second number in the series, 8 plus 4 is 12, the third number, 12 plus 3 is 15, the fourth number, and so on. Katona[1] reports that subjects who discovered or were told the above principle often learned the series at once, in a single repetition, and were usually able to recall it without error a week later. But those who memorized the series by the less adequate method of grouping by three's throughout often required several repetitions to learn it, and were seldom able to reproduce it correctly a week afterward.

It is obvious that the discovery of a general arithmetical principle in connection with the above series supplies it with an organization which is meaningful in high degree. It establishes relationships of a precise sort between the different numbers which comprise the series, so that if any particular number is forgotten it can readily be inferred or deduced in accordance with the principle. The series acquires a clear and definite pattern and becomes a meaningful unity.

Organization in different types of material can be achieved in many different ways. In memorizing a piano composition, for example, the rhythms, melodies, and harmonies of the music provide a basic organization of which virtually every learner takes advantage. However, the expert musician will perceive and utilize further organizing factors, for example, he will recognize the reappearance of a given

[1] *Ibid.*, pp. 11–20.

theme even though it is changed in key and tempo His capacity to discern and profit by such relationships is one reason for his superiority in learning and remembering musical material

In stylus maze learning, the mere association of each particular movement with the next, in terms either of successive kinesthetic stimulations or of guiding verbalizations, such as "left, right, forward, right," etc, yields little that could be termed "organization" in the sense in which Katona uses the word However, a maze does possess a fairly definite structure or pattern, and the responses of the maze learner can become more or less organized in accordance with it Thus a subject can group successive moves into small units, such as left right-forward, or can be aided in learning specific groups of movements by a perception of their spatial relationships to other preceding and succeeding groups Of special value to the maze learner is a comprehension of the general shape of the maze path as a whole, for example, that it approximates a circle, and first proceeds somewhat to the right, then turns and extends far to the left, and finally recurves and ends at a place near the starting point Such an understanding of a maze path functions like a general principle, even though it may be applicable only to the particular maze in question It helps to organize all the separate moves in the maze into an over-all form or pattern, and makes them meaningful by virtue of their relation to the general shape of the true path

In most verbal learning—unless it be of the rote memorizing variety[1] —general principles are likely to be the preeminent organizing factors When a student of psychology is reading about conditioning, he will encounter a number of general principles, for example, the basic principle that if two stimuli to which an organism is responsive are presented together, the reaction made to one stimulus may later come to be evoked by the other stimulus also The student who understands these principles is likely to retain them long and well Also, acquisition of the principles will make it easier for him to learn and remember the

[1] Rote memorizing means learning by repetition, with organization and understanding of the material at a minimum Some materials, such as lists of nonsense syllables, telephone numbers, statistical and chemical formulas which are not understood, lack significant internal relationships and thus usually can be learned only in rote fashion Most of what we learn however, does possess inner relatedness, is meaningful, can be organized by the learner, and so can be acquired by what Katona calls "learning by understanding," a far more effective method

various facts about conditioning which are presented in textbooks and lectures But a student who did not learn and understand the principles might find it difficult to organize and relate the many factual details involved in the study of the topic In consequence he might find the learning of this content an unduly difficult task, and his retention of it might be poor, as well

So far we have discussed the value of organization, especially the organization afforded by the acquisition of general principles, for the learning and retention of a specific material or activity Equally significant in the psychology of learning is the value of general principles from the viewpoint of transfer One of the earliest investigations dealing with this problem is that of Judd [1] In this experiment two groups of boys in grades V and VI practiced hitting with a dart a target submerged in water to the depth of 12 in Both groups practiced hitting the target at that specific depth only, but one group in addition received an explanation of the principle of the refraction of light rays through water During the practice the two groups were approximately equal with respect to the degree of accuracy they achieved Then both groups were given a different but related task, namely, that of hitting the target when it was under only 4 in of water The group which had been taught the general principle rapidly adjusted to the changed condition and exhibited a large amount of transfer The group which had had only the specific practice could not easily make the required adjustment and showed almost no transfer at all Judd's experiment was repeated, with some modifications, by Hendrickson and Schroeder[2] in 1941 Their results were essentially the same as those obtained by Judd, although the difference in amount of transfer between the two groups was smaller

Another experiment which demonstrates the transfer value of the acquisition and comprehension of general principles is that of Ruger [3] Ruger had his subjects solve a number of mechanical puzzles, many of which were similar in construction He found that a much greater amount of transfer from one puzzle to another was obtained by those subjects who discovered the general principle of solution of a particular

[1] Judd, C H The Relation of Special Training to General Intelligence *Educational Review*, 1908, vol 36, pp 28–42

[2] Hendrickson, G , and W H Schroeder Transfer of Training in Learning to Hit a Submerged Target *Journal of Educational Psychology*, 1941, vol 32, pp 205–213

[3] Ruger, H A The Psychology of Efficiency *Archives of Psychology*, 1910, No 15

puzzle, and who realized that many of the other puzzles could be solved by application of the same general rule.

Recently Katona[1] has published an extensive series of experiments dealing with the effect of different methods of learning on the acquisition, the retention, and the transfer of skill in performing a certain type of card trick, and in solving "match tasks" (matchstick puzzles). A primary aim of these experiments was to compare the value of (1) the rote memorizing of the solution of a specific trick (or tricks), and (2) the learning of the general principle by which a correct solution could be reached. Katona reasoned that the acquisition and understanding of a general principle should produce the kind of organization of the material which would improve the accuracy and duration of retention of a particular solution, and likewise facilitate transfer (application) of the learning to the solution of new but similar tricks. The remainder of this chapter will be devoted mainly to a presentation of certain of his many experiments.

KATONA'S CARD-TRICK EXPERIMENTS[2]

GENERAL PLAN

Katona's experiments with card tricks[3] have been selected for presentation in this chapter. The general plan of these experiments was as follows. The subjects were shown one or two versions of the type of card trick used. One group was told only the specific order in which the cards should be placed to do a particular trick (or tricks) and was instructed to learn that order. This group was called the "memorizing group." Another group was given an explanation of the general principle according to which the correct order of cards for a particular trick could be derived. This group was called the "understanding group." In many cases there also was a "control group," which was given tricks to solve without any practice or instruction whatever. Tests for the retention of the tricks learned were given after prescribed intervals of time. In addition, tests of transfer were made, that is,

[1] Katona, *op. cit.*

[2] Adapted from *ibid.*, especially pp. 32–54 and 263–268.

[3] In this chapter the card tricks were chosen for presentation instead of the more widely known match-task experiments because of their greater simplicity, the greater clarity of the experimental procedures used with them, and the more definite character of the results.

the subjects were given similar tricks to do without further aid from the experimenter

PROCEDURE

The Card Tricks. Katona used eight card tricks in all, each of which was constructed according to very similar principles The general nature of these card tricks was as follows The experimenter took a prescribed number of ordinary playing cards and made a deck[1] of them, with the faces down and so invisible to him He then laid out the cards, face up, on a table in a preannounced order, *e g*, alternately red and black, at the same time putting every other card, without looking at it, at the bottom of the deck from which he was dealing This procedure was continued until the entire deck had been laid out on the table Of course, such a trick is accomplished by making a specific prearrangement of the cards in the deck

Thus, to quote the experimenter's oral description to his subjects of one of the tricks "I take the top card" (of the prearranged deck) "and place it on the table It is a red card Then I take the next card and put it at the bottom of the deck without determining what it is I place the third card on the table It is a black card The following card I put undetermined below the others, while the next card, which is red, I put on the table " The procedure of alternately placing one card on the table and one at the bottom of the deck was continued until all the cards of the deck were laid out on the table The cards then appeared on the table in this order red, black, red, black, etc

According to Katona, a card trick of this type proved very satisfactory for experimental purposes It was novel and was interesting to the subjects Also this type of trick could be presented with many variations It was possible to vary the number of cards, *e g*, to use a deck of 6, 8, or 13 cards It also was possible to use a different order than that of alternating red and black For example, in one case the trick was to make a deck of the 13 cards of the spade suit and to lay them on the table in sequence from the ace to king inclusive, always putting every other card at the bottom of the deck Another

[1] The word "deck" does not refer to the whole deck of 52 cards A deck might consist of only 6 cards, or 8, or 13, or indeed any number

variation was to put two cards, instead of one card, at the bottom of the deck each time after a card was placed on the table

Katona used eight card tricks of the type described above The exact nature of each trick is shown in the accompanying table

Trick	Number and kind of cards to be laid out	Order in which cards are to be laid out	Number of cards to be placed at the bottom of the deck after each card is laid out
A	4 red and 4 black	Red and black alternating	1
B	The 13 cards of the spade suit	In sequence from ace to king inclusive	1
C	The 8 cards of the spade suit from ace to 8 inclusive	In sequence from ace to 8 inclusive	1
D	3 red and 3 black	Red and black alternating	1
E	4 red and 4 black	Red and black alternating	2 (except only 1 after the 6th card is placed on the table)
F	8 spades, 4 of even and 4 of uneven denomination	Even and odd alternating	1
G	4 red and 4 black	4 red, then 4 black	1
H	3 red and 3 black	Red and black alternating	2

The reader may not find it easy to understand exactly how the tricks are done unless he practices with an actual pack of cards, although study of Katona's instructions to the "understanding" groups on page 303 should be helpful Each of these tricks can be performed by prearranging the cards in the deck It is possible to learn a specific order for each individual trick, or a general principle from which the solution of any one of the tricks can be deduced The solution for each of the tricks (*i e*, the order in which the cards of the deck must be prearranged) is given on page 310

The Learning Methods After the subjects had seen the experimenter perform a "complicated version" of the card trick, they learned the solution of one trick (sometimes of two tricks) by one of the two methods described below

1 *The Memorizing Method* Each memorizing group received instructions, of which the following, for Trick A, is an example

I suppose you would like to know how to perform the trick I shall teach you a trick with four red and four black cards We want to arrange these eight cards so that the uppermost card in the deck is red, it is to be placed on the table The next card should be placed at the bottom of the deck without determining what card it is, then a black card should be placed on the table In order to achieve this goal you must take in your hand first, two red cards, then, one black card then two red cards, and at last three black cards [The last four phrases were written on a paper or on the blackboard] You are to learn this order so as to remember it We will, therefore, repeat three times four red and four black cards are to be arranged as follows first, two red cards, then [The experimenter pointed to the paper or the blackboard while the subjects read aloud]

2 *The Understanding Method* Each understanding group received instructions of which the following—also for Trick A—is an example

We must arrange eight cards We don t know in what order therefore we put eight question marks on the blackboard [See the schema below] The first question mark represents the first card, the second question mark the second card, and so forth The last question mark represents the last card According to the task, the first card should be a red card The second card should be placed below the others We do not know what it is, therefore it is represented by a question mark The third card must be a black card, while the fourth card is unknown (a question mark) [And so forth The letters and question marks in the second line of the schema were written on the blackboard while these directions were being given]

The four cards which are designated by letters on the blackboard are supposed to be on the table The four cards designated by question marks are still in my hand Now we must find out what cards these remaining question marks represent My last two moves were to put a black card on the table and an unknown card at the bottom of the pack The next card (that is, the first of the remaining question marks) must, therefore be a red card The following card, represented by the following question mark, has to be placed below the others and remains therefore a question mark Then follows a black card and lastly a question mark [Note the third line of the schema below]

Two question marks remain, that is, I have two unknown cards in my hand The first one, following a black card, must be a red card, while the next one remains a question mark This one being the last card, following a red card, must be black

Now we are ready to add up our findings First we have a red card, then another red card [reading the final line of the schema]

The schema which the experimenter put on the blackboard is reproduced herewith "R" means red, "B" means black, "?" means color unknown

```
?   ?   ?   ?   ?   ?   ?   ?
R   ?   B   ?   R   ?   B   ?
    R       ?       B       ?
            R               ?
                            B
R   R   B   R   R   B   B   B
```

It should be noted that in a *memorizing group* the subjects were simply told the correct order of the cards and required to repeat it a given number of times No explanation of the order was made to them, nor were they told why the prescribed order was the correct one In an *understanding group*, however, not only was the correct order eventually given, but also a method of logically deriving it was fully presented In a group of this type the subjects did not repeat the order aloud rather their behavior throughout the explanation was that of attentive listening

The teaching, and the learning and testing as well, were carried out with paper and pencil instead of with actual cards When a subject was tested for his memory of any trick, or for his ability to solve a new and different one, he wrote on a piece of paper what he thought the order of the cards should be

The procedure described above was used in all the five card-trick experiments presented below The first three experiments were of a preliminary nature, in that they involved the use of only four subjects each The remaining two experiments were more adequate quantitatively in that the subjects numbered 22 and 105, respectively

The Five Experiments

Experiment I The trick learned in this experiment was Trick A already described The subjects were four college students Two subjects were given, individually, the memorizing type of instruction and two the understanding type The learning and instruction process required 1 min for the memorizing and 4 min for the understanding subjects Immediately after this practice was finished, the subjects were tested for retention by being asked to write down the correct order of cards in the deck They all succeeded in doing this, but the memorizing subjects recalled the order more quickly Two weeks

later another retention test was given In this test one of the memorizers was unable to remember the correct order The other wrote down the correct order after some hesitation, but then changed it to an incorrect one In contrast, both of the understanding subjects gave the correct order in less than 2 min

Experiment II. In this experiment the trick was to lay out the 13 spades in sequence (Trick B) As before, the subjects were four college students, none of whom had served in Experiment I Two subjects were given the memorizing and two the understanding procedure The memorizers spent 4 min in learning the correct order of the cards, whereas the explanation given to the understanding subjects required 5 min Two retention tests were given, one immediately and the other 8 days later In the immediate test all four subjects correctly recalled the order of the cards, but the two memorizers did so more quickly In the later retention test neither of the memorizers was able to remember the order, but both the understanding subjects recalled it without error

Experiment III As in Experiment II, the trick was the one employing the 13 spades (Trick B) As before, there were four new subjects, two for each type of learning procedure In a retention test given immediately after the learning process, all four subjects correctly recalled the order of the cards Then, instead of another retention test, a transfer test was given immediately The subjects were asked to state (*i e*, to write down) how the cards should be arranged for Trick A already fully described Neither memorizer was able to solve the problem within 5 min, whereas the two understanding subjects succeeded after 2½ and 3 min, respectively

The results of these first three experiments suggest that (1) for immediate recall of the correct order of cards in a particular trick the memorizing method is equal to or superior to the understanding method, (2) for later recall—after 2 weeks in Experiment I and after 8 days in Experiment II—the understanding method is superior, and (3) for transfer, that is, for solving a similar card trick—as in Experiment III—the understanding method is likewise the better procedure

Experiment IV. Katona next carried out a small group experiment The *subjects* were 22 graduate students of psychology, all were entirely unfamiliar with card tricks of the type employed These subjects

were divided into three groups a memorizing group, an understanding group, and a control group, which numbered nine, nine, and four individuals, respectively The three groups were roughly equated for ability to solve these problems by having each subject classified by his instructor as very good or good, as average, or as poor, and by including within each of the three groups the same proportion of each of these classes The *memorizing group* first learned the order of cards for Trick A already described, then the order of cards for the trick in which eight spades from the ace to the eight inclusive were

TABLE I

The Number of Subjects in Each Group Whose Solutions to Each of the Six Tasks Were Correct or False

Task and trick	Understanding group		Memorizing group		Control group	
	Correct	False	Correct	False	Correct	False
Task 1 Trick A	6[1]	3[1]	8[1]	1[1]	0	4
Task 2 Trick D	6	3	1	8	1	3
Task 3 Trick E	5	4	2	7	0	4
Task 4 Trick F	6	3	5	4	1	3
Task 5 Trick C	6	3	7[1]	2[1]	0	4
Task 6 Trick G	9	0	7	2	3	1

[1] Means that the particular trick had already been explained or practiced during the previous learning period

to be laid out in sequence (Trick C) This learning was accomplished by having these subjects repeat the correct order of the cards five times for each trick, a procedure which required a total time of 4 min The *understanding group* listened to the experimenter's explanation of how the order of cards for Trick A could be derived (given in full on page 303) This procedure also required 4 min

The *test*, which began a few minutes after the completion of the learning period, consisted of six successive card-trick tasks This test was given to both the above groups and also to the control group of subjects who had never before seen any tricks of this type The subjects were allotted 4 min to write down the solution of each task, and their papers were collected after each such time interval

The results of the experiment are given in Table I "Correct" means that the subject's solution was complete and without error.

"False" means that a solution was partly incorrect, or was incomplete, or that no solution at all was produced within the 4-min time limit

Of the above tricks, A and C already are familiar to the reader Trick D was an easy variation of Trick A employing only 3 red and 3 black cards instead of 4 of each color Trick E was a difficult variation of Trick A, in that it required that (usually) two cards instead of one be put at the bottom of the deck after each card had been laid out on the table Trick F was another easy variation of Trick A, in fact it was identical with A except for the substitution of even and uneven denominations for red and black Trick G was sufficiently easy for intelligent persons to solve immediately as a rule, without previous knowledge of these card tricks

The results, like those of the first three experiments, indicate that for immediate recall the memorizing method is fully equal in value to the understanding procedure This point is readily seen when we compare the number of subjects in the two groups who could remember the correct order of cards for Trick A already practiced The data strongly indicate, however, that for the purpose of transfer—that is the solution of new but similar tricks—the understanding procedure was definitely superior In every instance in which both groups were required to solve a new trick, more of the understanding than of the memorizing subjects succeeded in doing so within the allotted 4 min It is also worth noting that Trick C was solved by almost as many subjects of the understanding group, for whom it was a new task, as it was by subjects of the memorizing group, who had previously repeated five times the order of cards requisite for its solution

Katona notes that the understanding subjects who were successful in the transfer situations usually did not recall the exact details of the schema according to which the correct order of cards for Trick A had been derived Instead these subjects remembered, as they put it, "the general scheme" or "the principle" of the solving procedure Katona also observed that the memorizing subjects who were able to solve the new tricks were successful largely because they happened to develop during the test an attitude of a "problem-solving" nature,[1]

[1] In this test, the development of a problem-solving attitude appears to be equivalent to getting the right "direction" in a problem situation requiring reasoning for its solution See Chap XXIII for a discussion of direction and its significance for thinking

so that they searched for a formula or a principle instead of merely trying to use the specific card orders which they had memorized

Experiment V. Katona's fifth experiment differed from the first four experiments in that the number of subjects was much greater, and the learning procedures were somewhat amplified As in Experiment IV, the subjects were instructed and tested in groups instead of individually, and control groups were employed

The *subjects* were 105 college students, divided into a memorizing group, an understanding group, and two control groups The groups were approximately equated in the same manner as in Experiment IV

The *experimental procedure* was as follows First each group saw the experimenter perform the 13-spade trick (Trick B) Then the experimenter, without explaining the trick, asked the subjects if they knew or had seen this trick or any similar one The few who answered in the affirmative were not used in the experiment A learning period of 4 min followed immediately During this time the *memorizing group* repeated five times the correct order of cards required to perform Trick A, and similarly repeated five times the correct order for the eight-spade trick (Trick C) The *understanding group*, as in Experiment IV, was not given specific repetitions of any order of cards but simply listened to the experimenter's explanation of Trick A The control groups had no learning or instruction period at all

Immediately after the learning a series of three tests was given The first was a transfer test utilizing Trick D, the easy variation of Trick A that also had been used in Experiment IV The second test, too, was a transfer test, and consisted of Trick E, the difficult variation of Trick A that likewise had been employed in Experiment IV The third test was simply a retention test of Trick A In this experiment 2 min instead of 4 were allotted for each solution After the above tests had been given, the subjects were asked not to discuss the tricks or to show them to anyone

Four weeks later the groups were given a second and entirely unexpected series of tests This series was preceded by another demonstration of Trick B (as before without explanation) The subjects were asked whether they had thought of the tricks during the 4-week period, had tried them out, or had shown them to anyone The test papers of those who answered any of these questions in the affirmative

were not scored As the table shows, these stipulations resulted in a decrease of the number of subjects actually used in the second series of tests

This second test series, like the first, consisted of three tasks, to be performed in 2 min each The first of these was another retention test of Trick A The second was the eight-spade trick (Trick C) This was a retention test for the memorizing group, since these subjects had learned the order of cards for this trick during the learning period For the understanding group, however, it was a transfer

TABLE II

For Experiment V, the Percentages of Subjects in Each Group Achieving Perfect Solutions

Test	Understanding group		Memorizing group		Control group	
	No of subjects	Percentage	No of subjects	Percentage	No of subjects	Percentage
First series	25		26		32	
Trick D		44		23		9
Trick E		40		8		3
Trick A		44[1]		42[1]		0
Second series	21		22		22	
Trick A		48[1]		32[1]		9
Trick C		62		36[1]		14
Trick H		52		18		0

[1] Means that the particular trick had already been explained or practiced during the learning period

test, since they had never seen or attempted the trick before The last test was Trick H, which was a transfer test for both groups Reference to page 310 will show that this trick was similar to Trick E, which had been used in the first test series Since a control group in an experiment of this type must be entirely unpracticed, the control subjects employed in the first test series could not serve again in that capacity and an entirely new group had to be selected

The results of Experiment V are given in Table II

The results of Experiment V are virtually identical with those of the other experiments As before, the two experimental groups were approximately equal with respect to their immediate memory for a trick previously presented This is seen when we compare the

percentages of subjects who succeeded in giving the correct order of cards for Trick A in the first test series. With respect to delayed retention, the understanding group was superior to the memorizing group, as a comparison of the percentages for Trick A in the second test shows. From the viewpoint of transfer, the understanding group always was superior, as is disclosed by the results for Tricks D and E in the first series, and for Trick H in the second series. It is noteworthy that in the second series, 62 per cent of the understanding group solved Trick C, which for them was a new task, whereas only 36 per cent of the memorizing group were able to give the correct order of cards for this trick, even though they had learned the order 4 weeks previously.

Solutions of the Eight Card Tricks Described on Page 302, i.e., the Order in Which the Cards Must Be Prearranged in the Deck

Trick	*Solution*
A	Red, red, black, red, red, black, black, black
B	Ace, queen, 2, 8, 3, jack, 4, 9, 5, king, 6, 10, 7
C	Ace, 5, 2, 7, 3, 6, 4, 8
D	Red, black, black, black, red, red
E	Red, black, black, black, red, black, red, red
F	Even, even, uneven, even, even, uneven, uneven, uneven
G	Red, black, red, black, red, black, red, black
H	Red, red, red, black, black, black

Discussion

The experiments of Katona are unique in that, prior to his work, no investigator had tried to compare directly the effects upon both retention and transfer of (1) the rote memorizing of a specific solution, and (2) the learning and understanding of the general principle by which the solution could be reached.

As the previous discussion has shown, the results of all of his five card-trick experiments are in complete agreement. They all point, in direct and unambiguous fashion, to the conclusion that for delayed retention and for transfer, learning the general principle by which a specific solution is derived is superior to merely memorizing a specific solution by rote. Thus, his results clearly demonstrate the value, for both delayed retention and transfer, of the kind of organization of the material learned which a general principle furnishes.

With respect to the significance of organization for retention, there are several studies other than those of Katona in the experimental

literature Psychologists have long known that retention is better for material which is more meaningful, which embodies more relationships among its several items For example, it has been amply demonstrated that poetry is better retained than are nonsense syllables,[1] that related pairs of words are better remembered than unrelated pairs,[2] that memory of the general substance or meaning of a prose selection is usually superior to that of a selection learned verbatim Such results are related to those obtained by Katona because the factors of meaning and relationship resemble general principles in their possession of organizing functions

If one inquires why, in Katona's experiments, the rote memorizing of a specific solution should have been inferior for retention of that solution, over periods ranging from 8 days (in Experiment II) to 4 weeks (in Experiment V), the answer might be in part as follows For Trick A (the one most frequently used for learning purposes) this type of learning consisted of the memorizing of the series "2 red cards, 1 black card, 2 red cards, 3 black cards" Such a series, in the absence of understanding of the principle according to which it is constructed, was almost entirely devoid of organization, *i e*, of significant inner relationships, and was meaningful only in the sense that it was known to be the solution of that particular trick Being a short series of items, it could be learned quickly even by the rote method But having little of an organized character, it was likely to be speedily forgotten And once it was forgotten, even if only partially, it could not be reconstructed by the subject, since its deficiency in organization made it impossible for him to derive or infer any individual item from any other item In contrast, the understanding method of learning yielded not only familiarity with a specific solution but also a comprehension of the general principle by which the specific order was derived Like the arithmetical principle discussed earlier in this chapter, this principle functioned as

[1] Radossawljevitch, P R *Das Behalten und Vergessen bei Kindern und Erwachsenen nach experimentelle Untersuchungen* Leipzig, Nemnich, 1907

Whitely, P L, and J A McGeoch The Curve of Retention for Poetry *Journal of Educational Psychology*, 1928, vol 19, pp 471–479

[2] Key, C B Recall as a Function of Perceived Relations *Archives of Psychology*, 1926, No 83

[3] English, H B, E L Welborn, and C D Killian Studies in Substance Memorization *Journal of General Psychology*, 1934, vol 11, pp 233–260

an organizing factor, which gave meaning to the individual details of the solution and made them parts of a unified pattern or whole In addition, the principle itself was well retained, so that even if a specific solution was forgotten, it could be reconstructed with the aid of the remembered principle

Why, in general, the retention of material learned by rote should be inferior to that of material learned with understanding is less easy to explain Katona suggests that the "neural traces," which are theoretically basic to all retention, are less well organized when learning is of the rote variety and are therefore less durable and persistent But whatever may be the explanation of these findings, there is no doubt as to their general validity Material which is well organized and well understood does tend to be well retained for long periods of time

Katona's findings with respect to the value of general principles for the production of transfer are similar to those of earlier experiments, *e g*, to those of Judd and others already referred to in this chapter However, few if any psychologists have laid as much stress as Katona does on the value of organizing the material of learning into meaningful patterns, and on the relative ineffectiveness for transfer of the rote memorizing of individual items Few also have devised experiments whose results so clearly justify such emphasis

From the viewpoint of transfer, the reasons for the superiority of the understanding method in the card-trick experiments seem very evident Since the memorizing groups had learned only one or two specific solutions, and had learned these without understanding, they had acquired little that could be profitably applied to the solution of new tricks for which the correct sequences of cards were radically different The understanding groups, however, had learned the principle by which the solution of a particular trick could be achieved Since all the tricks were solvable by the same method, the principle involved actually was *general* for the tasks employed, and therefore could be utilized to solve each one of them

In connection with the acquisition of general principles, Katona makes these further points, which are of considerable importance in the psychology of learning As we have several times remarked, many specific facts or items cannot be adequately comprehended unless there is available a principle which can serve to organize or integrate

them But, according to Katona, what we call a "principle" must be actively derived and understood by the learner if it is to have much utility for him If a principle is presented as a mere verbal formula which the subject is to memorize, it may be learned in a purely rote fashion, with no more understanding than usually attends the memorizing of a list of nonsense syllables or of telephone numbers It should be noted that in these experiments Katona did not at any time present to the understanding groups a simple rule by which the card tricks could be solved, and which could be memorized verbatim Instead he expounded a method by which the solution of a particular trick could be obtained The subjects who genuinely profited from this procedure were those who themselves discovered and grasped the *general* principle while listening to the derivation of a *specific* solution It seems probable that a procedure like this, in which a subject is led to discover a principle for himself, is the type most likely to yield that understanding of a principle which is essential for later productive use

The question of why the acquisition of general principles usually produces more transfer than is yielded by the memorizing of specific facts suggests a brief consideration and comparison of the two most important contemporary theories of transfer According to one viewpoint—the theory of identical elements expounded by Thorndike[1]—transfer depends on the number and importance of the elements which are present in both the training and the later transfer activities and situations Thus learning one maze, or one arithmetic problem, or one card trick may aid in the learning of another insofar as the two activities have elements or items in common This theory, which is presented in many textbooks of general psychology, has sometimes led to the conclusion that one can predict the probable amount of transfer from one activity to another by analyzing the two activities and noting what specific identities exist between them Thus one might endeavor to predict the probable amount of transfer from one card trick to another by noting the exact orders of cards required to solve each trick and then computing the number of identical elements, *i e*, of cards which are identical in color (or denomination) and position in the two sequences To illustrate, if the reader will turn to the

[1] Thorndike, E L *Educational Psychology* New York, Teachers College, Columbia University, 1913

solutions of the eight card tricks on page 310 and compare the order of cards required for solving Tricks A and E, he will see that the two orders contain four such identical elements, namely, the first, third, fifth, and sixth cards in each order

Katona's interpretation, however, opposes the identical-element theory He points out—as his results and those of other investigators clearly indicate[1]—that one cannot predict transfer in this simple fashion In his experiments, transfer did not occur on any such basis as the identical-element theory would require Memorizing a specific solution, a specific series of cards, did not carry over to other tasks in any rule-of-thumb manner What was important for transfer was not identities in the position of specific cards but rather an understanding of the solution procedure *as a whole* in terms of the general principle which underlay it Once this principle had been acquired, transfer occurred to other tasks on a considerable scale, but if it was not mastered, little if any transfer took place Thus a comprehension of the *pattern* of relationships involved in solving Trick A enabled 40 per cent of the subjects in the understanding group, in the first test series of Experiment V, to solve Trick E On the other hand, in the memorizing group only 8 per cent of the subjects could solve Trick E in spite of the fact that, as noted above, four of the eight "elements" in the two solutions are identical

To those interpretations of Thorndike's theory which suggest that a general principle itself can be regarded as an identical element,[2] Katona would answer that a "principle" is not an "element," but is a complex and more or less highly organized pattern, which behaves in a very different way during transfer than do "elements" learned by rote The critical factor for transfer, according to the Gestalt theories which Katona supports, is the *pattern* of relationship (*i e*, the organization) and not the number of identical elements

Whatever may be the outcome of this theoretical controversy among psychologists, the fact remains that general principles are perhaps the most important of all acquisitions from the viewpoint of transfer Katona, in discussing this point, says that "the material of learning is not necessarily the object of learning" and that "we do not learn

[1] For example, McKinney, F Quantitative and Qualitative Essential Elements of Transfer *Journal of Experimental Psychology*, 1933, vol 16, pp 854–864

[2] See McGeoch, J A *The Psychology of Human Learning* New York, Longmans, 1942, p 439

the examples, we learn *by* examples."[1] If we apply these statements to the present chapter, we would conclude that the object of the reader should not necessarily be to memorize the details of the experimental procedures or of the tables which give their results. These are the "material of learning" and the "examples." Although their presentation occupies the bulk of the chapter, they are set forth only to exemplify and make meaningful certain general principles in the field of learning, and in that respect they correspond more or less to the specific solutions of particular card tricks in the Katona experiments. The goal of the reader should be to learn and understand these principles and to see how they may be deduced from the material given, the aim of the writer should be to present the material in a manner corresponding to Katona's procedures with his "understanding" groups. According to Katona, these final points concerning the objectives of students and the responsibilities of teachers are of vital importance in the entire educational process. Only if such attitudes are present on the part of both students and instructors can knowledge be acquired which will be well retained, and which can be applied effectively to subsequent new situations.

[1] Katona, *op. cit.*, p. 125.

CHAPTER XIX

METHODS OF BREAKING UNDESIRABLE HABITS

INTRODUCTION

The question as to how an undesirable habit can best be eliminated is a problem which almost everyone encounters sooner or later. A person is likely to meet this problem first of all in his own behavior, unless he is one of those rare individuals who are either perfectly adjusted to their environment or wholly satisfied with their existing characteristics. If he escapes the problem in his own individual life, it is probable that he will meet it in connection with the troubles of some less fortunate friend or relative whom he is called upon to aid. If he becomes a parent, he will probably find that at times the undesirable habits of his children raise problems quite as crucial as their bodily health ever presents. And if he chances to become a psychiatrist[1] or a clinical psychologist, his lifework may consist largely of trying to change for the better the habits of his patients.

Since the problem of habit breaking is of such widespread importance, it is not surprising that psychologists have given great attention to it, especially in clinical work and in connection with their study of learning, inhibition, and forgetting. Their work and experience, together with the knowledge accumulated from psychiatric practice, have made possible the formulation of certain general methods of eliminating undesirable habits. It must be admitted that, since these methods are in the nature of general rules or principles, they cannot in themselves be expected to supply immediate solutions for all of the various specific difficulties that characterize each individual problem. Nevertheless, it is the general principles that furnish the essential basis from which one may develop detailed procedures adapted to varying individual needs.

A method of habit breaking is a method for bringing about the

[1] A psychiatrist is a medical doctor who specializes in the treatment of nervous and "mental" diseases and defects.

elimination of certain habitual responses The elimination of a response can be accomplished only by subjecting it to inhibition Inhibition, however, is not a passive but an active process That is,
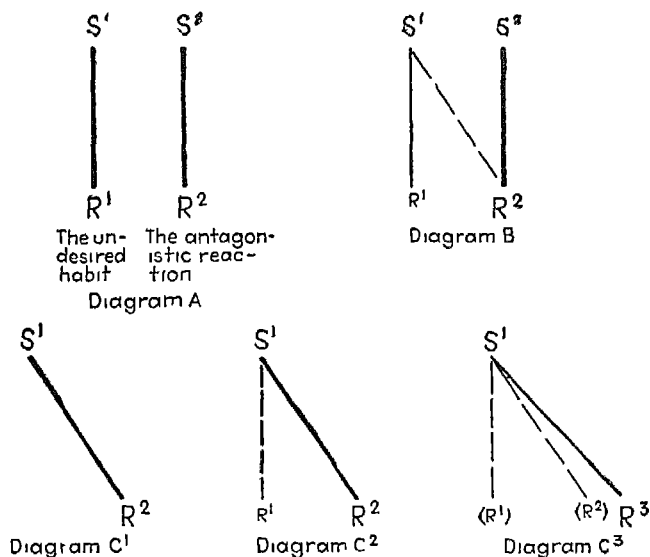
FIG 33 Diagrams Representing Habit Breaking as a Process of Reconditioning

In this and subsequent figures, S = stimulus R = reaction, and a line connecting any S and R indicates the presence of an association between them Heavy, light, and broken lines are used to indicate S R associations of great, medium, and small strength, respectively

Diagram A represents the circumstances prior to any reconditioning The individual possesses the undesired habit (R') and also a reaction (R^2) which is antagonistic to it Stimuli which evoke the two responses are designated by S^1 and S^2 respectively Since the two reactions have never been associated, no reconditioning has occurred

Diagram B represents the results of the performance of the antagonistic reaction in the presence of the stimulus for the habit Since R^2 is stronger than R^1, the latter occurs only weakly if at all (as indicated by the small size of the letter) Thus an association between S^1 and R^2 begins to be formed

Diagrams C^1, C , and C_3 represent three possible outcomes of the reconditioning process

In Diagram C^1, S^1 no longer evokes R^1, but instead arouses the new reaction only R^2 has not only completely inhibited R^1, but also has entirely displaced it

Diagram C^2 represents an alternative possibility Here R^1 is only partly inhibited, *i e*, it is still evoked by S^1 but at greatly reduced intensity

Diagram C^3 represents another possible outcome R^1 has been effectively inhibited but R^2 has not displaced it Since R^1 and R^2 are mutually inhibitory, neither occurs as a response to S^1 In such cases, some new reaction (R^3) eventually may displace both R^1 and R^2

an existing old response can be inhibited only by developing, through learning, a new reaction which is antagonistic to it, and which is superior (or at least equal) to it in strength Therefore, any successful method of habit breaking requires the development of new reactions which are capable of inhibiting the undesirable habit

Furthermore, for this inhibition actually to occur, it is necessary that the new reaction be aroused in situations which contain stimuli for the old response as well. Otherwise, the two reactions could not be stimulated simultaneously, and under ordinary conditions the development of a learned inhibition of one reaction by another requires that the two responses appear together during the training. Finally, if the new reaction is to inhibit the old response effectively and permanently, a process of *reconditioning* (or *inhibitory conditioning*) must take place. This reconditioning, as Fig. 33 shows, may have three possible outcomes. First, the stimulus which formerly produced the old, undesired response may elicit the new reaction only (Diagram C[1], Fig. 33). In this case, the new reaction *completely displaces* the habitual response. Second, the stimulus for the habit may arouse the new reaction strongly, but may also elicit the habitual response in a weakened or fragmentary form (Diagram C[2], Fig. 33). In this case, the new reaction *partially displaces* the habitual response (*partial inhibition*). Third, the stimulus for the habit may evoke neither the new reaction nor the habitual one. Instead, either it may produce no response at all (*i.e.*, the individual becomes "indifferent" or "negatively adapted" to the stimulus) or it may elicit some entirely different reaction (Diagram C[3], Fig. 33). In this case, the new and the old responses *mutually inhibit* each other (*mutual inhibition*).

The objective of any habit-breaking procedure, therefore, is to retrain the individual so that new and more desirable reactions may be aroused in situations which formerly elicited only the old, undesirable habits. The practical rule, as Guthrie states it in his *Psychology of Learning*,[1] is to "find the cues that initiate the action . . . and practice another response to those cues" (page 138).[2]

From the viewpoint of this rule, it may be said that the four general methods of habit breaking which we shall describe constitute four different ways by which Guthrie's prescription can be effectively followed.

[1] Guthrie, E. R. *The Psychology of Learning*. New York, Harper, 1935. Three of the four methods of habit breaking outlined below, together with many of the specific illustrations given, are taken from this book, especially from Chap. V, pp. 64–84, and Chap. XI, pp. 135–147.

[2] Guthrie, in his most recent work, states the general principle of reconditioning as follows: "When a stimulus is given and its response prevented, the stimulus loses its ability to call out that response." (Guthrie, E. R., and A. L. Edwards. *Psychology, a First Course in Human Behavior*. New York, Harper, 1949, p. 75.)

Before proceeding to a description of particular methods of habit breaking, it should be emphasized that the success of any of these methods depends mainly on the good judgment and perseverance of the individual himself This statement holds true when an individual is trying to recondition himself, regardless of the amount of aid and guidance that he may be receiving It holds equally true when he is attempting to retrain some other person In particular, the importance of strong and enduring motivation cannot be overestimated Reconditioning cannot be expected to occur "automatically" by virtue of the mere presence of the stimuli and the occurrence of the reactions described Unless the establishment of the new S¹-R" association is in harmony with the individual's basic attitudes in the relearning situation, and contributes to the attainment of some goal toward which he is motivated, it is unlikely that the new association will ever be formed Certainly no one can expect to break a long-established habit unless he is genuinely desirous of doing so, and unless he is willing to exert his utmost effort to check the undesired responses and to make vigorously the new reactions which are to displace them Furthermore, the individual must avoid becoming discouraged by the difficulties and apparent failures which he may encounter, especially at the beginning of the reconditioning process, and must fortify himself with as much confidence in ultimate success as possible Although it is true that effective methods of habit breaking are available, it is equally true that no easy methods exist

It is also important to note that the habits of which we have been speaking need not be of the explicit, externally observable type On the contrary, the responses to be corrected are very often undesirable thoughts or ideas Similarly, the new inhibiting reactions are very frequently thought responses Indeed, thoughts, especially those which take the form of "good resolutions," or those whose content is encouraging or reassuring in nature, are among the most effective of inhibitors The individual who displays marked self-control is usually a person in whom thought responses are capable of preventing actions which he deems undesirable Thus "right thinking," as the term has been traditionally used, may signify the formation of thinking habits which will be of great value in guiding conduct when some serious problem of habit elimination arises

METHOD I THE INCOMPATIBLE-RESPONSE METHOD

The most important and the most widely used of the methods of habit breaking described by Guthrie is one in which the undesired habit is eliminated by "*the action of incompatible responses*" (page 69) The objective of this method is to find and establish a new reaction (1) which is antagonistic to the habitual response, (2) which can be conditioned to stimuli that produce the habitual response, and (3) which can be made sufficiently strong to inhibit the habit when the critical stimuli are present As will be evident later, this method differs from the others, in that the nature and the actual production of the new, inhibiting reaction are a matter of concern and careful planning from the very beginning of the treatment (Figure 33, which represents habit breaking as a process of reconditioning in general, equally well illustrates the specific method of incompatible response)

A simple illustration of this method may be found in the old advertising slogan, "Reach for a Lucky instead of a sweet" (a bit of advice which naturally did not please the candy manufacturers) In this example, eating candy is the supposedly undesirable response, and smoking a cigarette is the supposedly desirable one Obviously, the act of smoking might come to inhibit candy eating entirely, if it were made the dominant reaction of the two, and if it became conditioned to the various stimuli which originally produced the response of candy eating

Experiences in the field of child training offer innumerable illustrations of the use of the incompatible-response method An example is the well-known experiment of Jones[1] in which the fear of rabbits in a thirty-four-months-old boy was eliminated by having him eat candy repeatedly while a rabbit was visible in a wire cage nearby Since the positive reactions to the candy (*i e*, approaching and reaching, and a related positive emotional response as well) were stronger than the negative responses to the rabbit (*i e*, running away and the emotional reaction of fear), those positive reactions finally became conditioned to the rabbit, inhibited the negative responses, and so broke the undesired habit Indeed, the treatment was so successful that the child actually came to like and to play with the rabbit

Another example of the use of the incompatible-response method in

[1] Jones, M C The Elimination of Children's Fears *Journal of Experimental Psychology*, 1924, vol 7, pp 382–396

child training is the technique devised by Mowrer[1] for treating nocturnal enuresis (bed-wetting during sleep) In this technique the child sleeps on a specially constructed pad which has fine wire inside it The wires in the pad are connected with a battery outside the bed If the child wets the pad, the wires are short-circuited and a bell rings The child then awakens, and, in conformity with the instructions he has received from his parents or other adults, gets up, breaks the circuit by opening a switch, and goes to the bathroom whether or not he needs to urinate further When the procedure succeeds, the response of awakening becomes conditioned to the stimuli arising from the distention of the bladder, which have repeatedly preceded urination and the consequent ringing of the bell The above technique, together with other ingenious reconditioning procedures for treating enuresis, are fully described by Smith [2] His discussion shows clearly, however, that the full cooperation of the child, and therefore a strong favorable motivation on his part, are essential for success, and that merely having the child awakened at the appropriate time by the automatic ringing of a bell will not effect a cure

The incompatible-response method also is illustrated by the use of punishment as a means of habit breaking The term "punishment" signifies a kind of stimulation which an individual finds disagreeable or painful, or which he tries to avoid Technically speaking, when punishment succeeds it does so only by bringing about a new, often negative reaction strong enough to inhibit the undesired response that was punished (Hence punishment has the function of S^2 in Fig 33)

One of the best known contemporary applications of a punishment technique is the method for treating chronic alcoholics devised by Voegtlin [3] In each treatment by this method, an injection productive of violent nausea is given in close conjunction with the presentation of alcoholic liquors Specifically, the procedure is as follows The patient must be in a hospital, and is given no solid food for at least 12 hr before each treatment The injection, the essential ingredient of which is 50 grains of emetine HCl, is given hypodermically Violent

[1] Mowrer, O H , and W M Mowrer Enuresis—a Method for Its Study and Treatment *American Journal of Orthopsychiatry*, 1938, vol 8 pp 436–459

[2] Smith, S *The Psychological Origin and Treatment of Enuresis* Seattle University of Washington Press, 1948

[3] Voegtlin, W L The Treatment of Alcoholism by Establishing a Conditioned Reflex *American Journal of Medical Science*, 1940, vol 199, pp 802–810

nausea usually is brought about within 2 to 8 min A few seconds before the onset of the nausea, and likewise throughout its early stages, the patient drinks liquor (especially his favorite variety), inhales its odor deeply and repeatedly, and sees on a table in front of him a conspicuous array of liquor bottles Usually a total of four to seven treatments over a period of 3 to 7 days is administered In addition single treatments to the extent of one every 30 to 90 days throughout 1 year are commonly necessary to maintain (reinforce) the inhibitory conditioning The method apparently cures a considerable percentage of cases [1] However, many psychiatrists[2] believe that its success requires favorable attitudes which are by no means present in all alcoholics, for example, the full cooperation of the patient and a strong desire on his part to be cured Furthermore, the likelihood of success is greatly increased by combining with the reconditioning technique various psychotherapeutic[3] procedures of the traditional types

It is interesting to note that these traditional psychotherapeutic procedures also exemplify the incompatible-response method, in that they aim to develop in the patient new reactions which may inhibit and often replace the undesirable responses which constitute the ailment under treatment Thus, in the course of the lengthy conversations which the psychiatrist has with his patient, the latter is led to speak freely about his symptoms and other troubles The psychiatrist explains the causes of these difficulties and designates the stimuli which produce the symptoms He also encourages the patient to believe that he can and will be cured In situations of this kind, the psychiatrist and his behavior (especially his actual words of explanation and encouragement) become stimuli for more favorable reactions on the part of the patient—more courage, for example, more self-confidence, and more understanding At the same time the patient is actually exhibiting his fears and other symptoms, or at least is thinking and talking about them Hence, an opportunity is afforded for the de-

[1] Voegtlin, W L Conditioned Reflex Therapy of Chronic Alcoholism, Ten Years Experience with the Method *Rocky Mountains Medical Journal*, 1947, vol 44, pp 807-812

[2] See, for example, Carlson, A J The Conditioned Reflex Therapy of Alcoholic Addiction *Quarterly Journal of Studies of Alcohol*, 1944, vol 5, pp 212–215

[3] "Psychotherapeutic" refers to "psychotherapy," a word which literally means "mental healing" The term covers all psychological types of treatment

velopment of an association between the more favorable reactions mentioned above and certain of the stimuli which evoke the symptoms The psychiatrist hopes that in time the more desirable reactions will become strongly conditioned to the stimuli for the injurious habits and will finally inhibit the latter altogether If this occurs, the patient is certain to be greatly benefited, and may even be permanently cured

As we have said, all methods of habit breaking require the inhibition of the habit by some other reaction, and the conditioning of new responses to the stimuli for the habit But, regardless of the method of habit breaking employed, difficulties arise which are not the fault of the method itself As Guthrie points out (page 139), one cause for the difficulty which is often encountered during the attempt to eliminate an undesirable habit is the number and variety of stimuli to which the habit has been conditioned Consider smoking, for example One might suppose that the act of smoking was conditioned only to the stimuli furnished by the pipe, cigar, or cigarette itself In actuality, the act of smoking can become conditioned to any stimulus which has ever been present while smoking was going on Thus, the act may be conditioned to the situation of just having finished eating, to studying, to playing cards, to seeing other people smoke, to talking with friends or strangers, to all the various places where the person has smoked, to internal tension or "nervousness" from any source, to innumerable thoughts, feelings, and movements of the individual himself, and so on indefinitely One reason why a well-established smoking habit is hard to break is that some kind of antagonistic reaction must be conditioned to every one of the stimuli which elicit smoking Otherwise, some stimulus which evokes the response of smoking will fail to produce any antagonistic reaction and smoking, being now quite uninhibited, will naturally occur

A further illustration of the difficulty created by a multiplicity of controlling stimuli is to be found in the case history of a certain drug addict This patient, a middle-aged, married man, was sent to a sanatorium for treatment While there he learned to do without the drug, that is, he learned to make reactions other than taking the drug in a great variety of situations characteristic of the everyday routine of living in the sanatorium He was finally returned home as cured However, he had not been home long before he had a

quarrel with his wife, following which he at once resumed the drug habit One reason for his relapse was that since his wife had not been present in the sanatorium he had not specifically learned to do something other than taking drugs after quarreling with her. Responses inhibitory to drug using had been conditioned to many of the stimuli for the habit, but no antagonistic reaction had been conditioned to the strong stimulus provided by domestic altercation

This factor of stimulus multiplicity explains many "lapses" (*i e*, recurrences of some undesirable reaction), since these are often due to the accidental presence of some unsuspected stimulus which has been associated with the habit and for which no new response has been developed For example, a particular fear or anxiety may disappear for a while, then suddenly reappear, thus refuting the belief that it had been entirely overcome To anyone, and especially to the neurotic patient, these recurrences of the undesired response may seem very mysterious and are often productive of alarm and profound discouragement Under such circumstances, the individual should remind himself of the fact of stimulus multiplicity, and should realize that, although this fact makes many habits hard to break, it does not change in any respect the methods of breaking them

METHOD II. THE EXHAUSTION METHOD

Guthrie's second method of habit breaking involves the *exhaustion of the undesirable response* by continuous repetition of it When a response is actually exhausted, it can no longer be aroused by its customary stimuli But since an individual always continues to react in some way, he now makes a response which is different from the exhausted one, although the stimuli which initially produced the latter are still present Hence, an opportunity is afforded for the conditioning of a new response to the stimuli for the undesired one (This method is depicted in Fig 34)

As Guthrie points out (page 72), an excellent example of this method is to be found in the kind of "horse breaking" which is practiced on many Western ranches The purpose of the horse breaker is to eliminate the responses of anger, struggle, and resistance on the part of the animal, and to substitute for them reactions of a docile and obedient type In order to accomplish this, the horse is first roped and thrown and blindfolded Then a heavy saddle is

cinched tightly upon it and painful bits are forced into its mouth The rider mounts, the blindfold is removed, and a struggle between horse and rider of the "let-'er-buck" variety ensues If the horse fails to dislodge its rider, the animal sooner or later becomes exhausted Its frantic struggles cease, and it either comes to a standstill heaving and trembling, or trots off with its rider in quite docile fashion In either case, new reactions have been produced, and since the saddle bit, reins, rider, and other stimuli for the original fighting responses are still present the new reactions can be conditioned to them
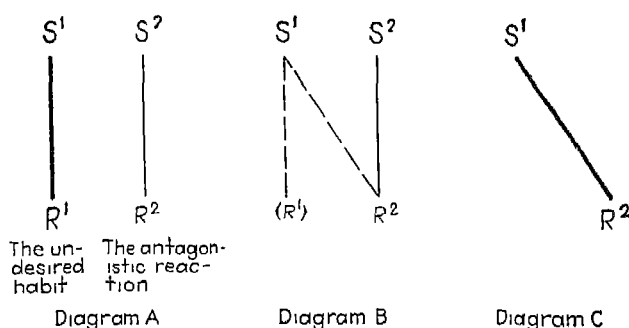
FIG 34 Diagrams Representing Habit Breaking by the Exhaustion Method

(The circumstances prior to any reconditioning are shown in Diagram A, Fig 34)

Diagram A represents the initial reaction in a given situation A stimulus (S^1) produces the habitual response (R^1) However, the situation includes a stimulus (S^2) which would produce an antagonistic reaction (R^2) were it not for the greater strength of R^1

In Diagram B, as a result of continuous repetition, R^1 has been so weakened (as the relative size of the letters indicates) that R^2 has become the stronger reaction of the two Hence R^2 now occurs in the presence of S^1

Diagram C represents the completion of the reconditioning Instead of the undesired habit, S^1 now regularly evokes R^2

An illustration of the use of the exhaustion method in child training is provided by a three-year-old girl who had developed the dangerous habit of striking matches and watching them burn This she did with all the matches she could find in the house, in spite of scoldings and other punishments (using these devices would exemplify the incompatible-response method) One afternoon following a particularly flagrant instance of match burning, her mother decided to try a different mode of attack She took her daughter into the yard gave her six large boxes filled with matches, and forced her to strike every match in them The child soon tired of this ordeal and was reduced to tears, outcries, and entreaties But her mother was in

flexible For two hours the child was compelled to stay there and to strike one match after another This emotionally arduous and physically exhausting experience is reported to have effected a permanent cure of the habit

Methods of the exhaustion type are often used clinically For example, a neurotic young woman was afraid to ride in an automobile, except for a few miles over familiar roads, and had an especially intense fear of bridges and tunnels One day her doctor directed that she be driven from her home to his New York office The distance was nearly 50 miles, and the route involved crossing a number of high bridges and traversing the Holland Tunnel On the morning set for the ride the woman was in a condition of panic, with violent nausea faintness, and an approach to hysteria Her terror persisted during much of the ride, but it diminished as she neared the refuge of her physician's house The return trip provoked little or no emotional disturbance, and subsequent journeys over the same route proved increasingly easy for her Apparently some measure of exhaustion of the fear reactions was induced, which permitted other more normal responses to appear while stimuli for the fear reaction were still present

The exhaustion method, therefore, achieves exactly the same ultimate result as does the incompatible-response method The essential difference between the two methods lies in the practical procedures which characterize them In the incompatible-response method, the habitual response, however intense it may be, is inhibited by the presence of another even stronger reaction, which is antagonistic to it Hence, the person who is using this method must carefully select the new inhibiting reaction and contrive to have it occur when stimuli for the undesired habit are still present On the other hand, in the exhaustion method, the primary aim is to exhaust the undesired reaction by repetition It is true that when this exhaustion has occurred, some new response (which originally was weaker than the exhausted one) must be made, if the method is to be successful But the exact nature of this new reaction usually is left more or less to chance

A further point in connection with the exhaustion method is that the exposure to a critical stimulus, which it requires, may have beneficial results other than those which devolve upon the actual exhaustion of the undesired response For example, it sometimes happens that

a deliberate confronting of a feared stimulus reveals to the individual that the object is not nearly so frightening and terrible as he had thought Under such circumstances, the fear reactions may abate quickly, and opportunity for the necessary reconditioning may be speedily afforded Guthrie points out in his *Psychology of Human Conflict*[1] that the victim of a phobia[2] usually takes every precaution to avoid any encounter with the feared stimulus, and therefore deprives himself of any opportunity to be reconditioned In such cases exposure to the stimulus (either through self-initiated effort or under the direction of the psychiatrist) may bring about the favorable result described above

The exhaustion method has been characterized as one of the "sink-or-swim" type Many thoughtless and "nerveless" people regard it as the best possible method for ridding other individuals of what they term their "silly" fears and weaknesses As a matter of fact, however, the method should be used only with caution Obviously, one cannot always be sure that the undesired response will be exhausted If it is not, then the habit may be fixated more strongly than ever, and the person's confidence in his ability to break it may become seriously impaired In addition, the exhaustion of a response at a particular time does not preclude its reappearance on a subsequent occasion Unless reconditioning occurs while the response is temporarily reduced or abolished because of exhaustion, the method cannot be expected to succeed The exhaustion method of horse breaking often fails to eradicate the fighting reactions, and the horse may remain a "bucker" all its life Similarly, forcing a child to go through with a public recitation or a musical performance which he dreads, without trying to diminish his fears beforehand by the incompatible-response method, may create a life-long horror of such situations

METHOD III THE TOLERATION METHOD

The third method described by Guthrie is one in which attention is turned primarily to the stimuli for the undesired habit, rather than to the response itself or to any possible substitute for it It is a method in which the individual is led to develop a *slowly increasing toleration* for the stimuli for the undesired reaction The procedure required

[1] Guthrie, E R *The Psychology of Human Conflict* New York, Harper, 1938, p 277

[2] A "phobia" is a persistent and usually intense fear of something not commonly feared or regarded as dangerous

by the toleration method is simply to present the stimulus for the habit at an intensity so slight that the undesired response is, at most, only very weakly aroused Under these conditions, although the stimulus for the habit is at least partially or weakly present, the habit itself is not fully elicited by it Hence, as in the first two methods, opportunity is given for making a new reaction which may be conditioned to the stimulus for the habit As in the exhaustion method, the exact nature of this new reaction may not be predetermined On later occasions, the strength of the stimulus is gradually increased, great
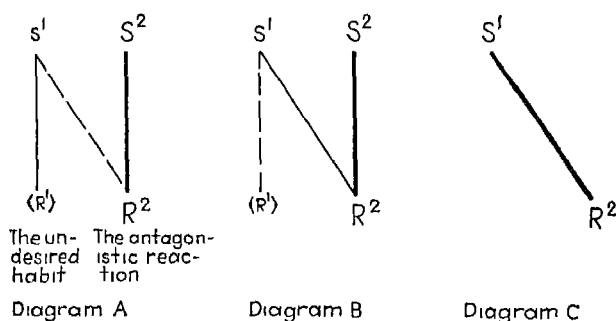
FIG 35 Diagrams Representing Habit Breaking by the Toleration Method

(The circumstances prior to any reconditioning are shown in Diagram A, Fig 33)

Diagram A represents the presentation of S^1 at such slight intensity (as indicated by the small size of the letters) that R^1 (the undesired habit) is aroused only very slightly, if at all Hence another stimulus (S^2) can arouse an antagonistic reaction (R^2) in the presence of S^1, and reconditioning can begin

Diagram *B* represents a later stage of the method S^1 is presented at greater intensity, but the progressive conditioning of R^2 to S^1 prevents the appearance of R^1 in any but a very slight degree

Diagram C represents the completion of the reconditioning Now S^1, even when it is present at full intensity arouses R^2 instead of R^1.

care being taken that it shall never be intense enough to arouse the undesired response too strongly Finally, if the method succeeds, the original stimulus may be present at its full strength without exciting the undesired response (This method is depicted in Fig 35)

Guthrie illustrates the method (page 71) by another type of horse breaking, the kind favored in the United States Army Since the undesired responses are fear, anger, and resistance on the part of the animal, this method requires that the horse be adapted to the work of carrying a rider by a process so slow and cautious that those reactions are never strongly aroused To this end the horse learns to tolerate a saddle upon its back by first having a light blanket laid upon it, then a sack with a little grain in it, and so on Similarly,

it is gradually accustomed to the bit in its mouth and to the presence of a rider

Jones's treatment of the small boy who was afraid of rabbits (a study to which we have already referred) also illustrates the toleration method. In this particular case, it was soon found that if the rabbit in its cage was placed very near the child, it was a stimulus so intense that the boy cried and would not eat the candy at all. Hence the experimenter was obliged to start the treatment with the rabbit so far away in the room that it was not a sufficiently strong stimulus to excite the undesired fear responses. When this was done, the boy would continue to eat the candy, though he also continued to be somewhat disturbed by the distant animal. At later sessions the rabbit was gradually moved nearer and nearer, until finally the child would tolerate it very close to him and would even stroke and caress it without showing any fear.

Psychiatrists and clinical psychologists employ this toleration method very frequently. As Guthrie remarks (page 76), the fear of cats can sometimes be treated by giving the patient a kitten to bring up (provided, that is, that he is not equally terrified by kittens). If the patient can react more or less normally to the kitten in the course of feeding and caring for it, in time he may be able to react normally to the adult cat into which the kitten eventually grows. Similarly, if a neurotic patient fears to take a long walk alone, he may yet be able to walk a certain small distance—say, half a block—without too great an emotional disturbance. After having become accustomed to walking that distance, he can perhaps walk a full block alone, then two blocks, and so on.

Guthrie, in his *Psychology of Human Conflict*,[1] describes the treatment of a fear of mice by the toleration method. The patient was a woman whose phobia of the animal was so intense that she employed a skilled workman to "mouseproof" her house by blocking off or covering with wire netting every avenue (including the tops of the two chimneys) by which a mouse might conceivably get into her home. One result of these and other precautions was that it had been years since she had seen a mouse, or had actually been frightened by one. (As Guthrie points out, the skill with which an individual avoids the object of his phobia prevents him from being reconditioned by the

[1] Guthrie, *op. cit.*, p. 282.

incompatible-response or exhaustion methods) Nevertheless, the mere mention of the animal at a social gathering was enough to cause her to leave the room Guthrie's treatment for the elimination of the phobia consisted of the following series of steps First she was inured to talking about mice with the psychologist Then she got used to the presence in her room of a small china mouse Next she became accustomed to the presence of a more lifelike mouse made of rubber Presently she learned to tolerate a stuffed white mouse, and finally she learned to endure without distress a live mouse in a cage Since in our culture the capacity to tolerate mice running freely about the house is not required, the patient was not subjected to this condition, and her fear was regarded as cured Of course, the repeated conversations about mice and about the fear of mice throughout the treatment probably contributed materially to its success

To some people this toleration method may seem too slow and tedious, to others of the "treat-'em-rough" school, it may seem a process too "soft" and too "gentle" to yield dependable results However, it must not be thought that the method requires no effort on the part of the individual On the contrary, the subject must be willing to try continually to make the stimulus as strong as he can stand it, *i e*, as intense as it can be without overstepping the limits of his toleration at the time Patience, perseverance, and self-control are demanded by this method, just as they are by any other Some methods of habit elimination perhaps are less painful than others but, as we have said, no really easy method of habit breaking exists

METHOD IV THE CHANGE-OF-ENVIRONMENT METHOD

A fourth method of habit breaking, an important one though it is not mentioned specifically by Guthrie, is the *removal of the stimuli for the undesired habit* Evidently, if these stimuli could be subtracted from the individual's experience, either partly or completely, the occurrence of the habit in question would be correspondingly reduced or eliminated The removal of the stimuli, whether partial or complete, can be accomplished in either of two ways They may be eliminated from the environment in which the person actually is living, or the individual may move to a different environment in which the stimuli may be less common, or even absent altogether

How much benefit can be expected from changing the environment

in which the person lives depends largely on whether the nature of the stimuli for the undesired habit is such as to make their removal feasible. If these stimuli—to recall some of the cases mentioned in this chapter—are such things as alcoholic liquors, tobacco, cats or mice—it is evident that stimulus removal in the literal sense of the term would be virtually impossible. On the other hand, if the stimuli include such modifiable factors as, for example, the attitudes of other members of a person's family, then beneficial changes in that person's habits often can be effected.

Thus, if the person to be treated is a child, much good usually can be accomplished by persuading one or both parents to change certain of their attitudes toward him. The mother and father typically are the most important influences, *i.e.*, sources of stimulation, in a child's environment. If either of them has been, for example, overcritical, domineering, neglectful, or overprotective, a reform of such attitudes (and consequently a change in the parent's overt behavior toward the child) may aid greatly in modifying the child's undesirable responses. In the case of an adult also, it is frequently possible to effect useful changes in the home environment. For example, the departure of a mother-in-law often will remove the stimuli that have been primarily responsible for an adult's habitual tension or irritability and thus largely eliminate those reactions.

Usually, however, the critical stimuli cannot be effectively removed from the environment in which the individual is living. Hence, the change-of-environment method is likely to involve the removal of the person himself to new and different surroundings in which the stimuli for the undesirable habits will perhaps be less ubiquitous, less intense, or even absent entirely. Such devices as taking a trip or going to a sanatorium are familiar examples of this procedure. The method is widely recommended by physicians, who often advise a well-to-do patient to go on a sea voyage (as well as to take vitamins, change his diet, and abstain from coffee, tobacco, and alcohol). Clinicians also employ the method frequently, though usually with more discretion. To most people the method, if feasible, seems both easy and pleasant. Many of us often have felt that if we only could go to some new place, get a new job, or make new friends, our undesirable characteristics would be miraculously altered.

Sometimes, a radical change of environment undoubtedly is called

for An example is the case of a college student living at home who began to develop a speech difficulty His parents not only were quite unsympathetic but even went so far as to laugh and jeer at his disorder Unless the parents' attitude could be altered (a procedure which would change the environment in which he lived), it would clearly be desirable for the boy to go to a college away from home, where he would be free from daily contact with his family

In many other cases, moving to a new environment can be helpful, provided the stimuli for the undesired habits are present less frequently or less intensely than they were in the individual's former surroundings As we have said, if the critical stimuli can be thus reduced, the undesired responses will be aroused less often or less strongly, and the task of developing new reactions which are antagonistic to them may become less difficult Thus one reason why the habit of drinking alcohol to excess can better be treated in a hospital or sanatorium than in a patient's home is that the new environment probably contains fewer of the many stimuli to which the habit has been conditioned

However, the method of "going somewhere else" can rarely be depended upon as the sole means of cure For one thing, most environments are fundamentally similar, and as a rule the so-called "new" environment also contains stimuli which arouse the undesired habits Suppose, for example, that an individual is afraid of encountering certain people If he moves to a new environment, he will of course meet new people But some at least of these new people are likely to be so similar to those whom he feared that he may soon find himself just as apprehensive as before In addition, the individual usually must return to his old environment sooner or later Unless he has learned in the new environment how to adapt more successfully to the old one, he may gain no lasting benefit from the change The case of the drug addict who was "cured" while he remained in the sanatorium but relapsed when he returned home illustrates this point

In our opinion, the variety of change-of-environment methods discussed above might finally be evaluated as a procedure which may often be worth trying, but which is never to be relied upon as an instrument for permanent cure

SUMMARY

The four methods of habit breaking which we have described may be briefly characterized as follows In the *incompatible-response method*

the individual consciously tries to devise, produce and establish some new reaction suitable to inhibit the undesired habit. In the *exhaustion method* the individual deliberately exposes himself to the stimuli which arouse the undesired response, in the hope that continued production of that response will exhaust it and so give opportunity for the occurrence of some more favorable reaction in the given situation. In the *toleration method* the individual attempts, cautiously and gradually, to inure himself to some stimulus productive of undesirable responses by subjecting himself to that stimulus at first at very slight, later at increasing intensities. In the *change-of-environment method* the individual tries to remove the stimuli for the habit from his present surroundings or, more usually, removes himself to a different locality in which those stimuli may be less frequent. Each of these methods, of course, can be employed either by a person who is seeking to effect changes in his own behavior or by a psychologist or a psychiatrist who is trying to cure a patient.

The question as to which of these methods is the best cannot be answered in any simple or categorical fashion. For one thing, the value of a given method depends on the nature of the habit to be eliminated, on the characteristics of the person in whom the habit is established, and on the various attendant circumstances which are involved in every individual case. Furthermore, the use of one method in no way precludes the use of other methods also. Even the exhaustion and the toleration methods, which might seem to be mutually exclusive, can be used with the same individual on different occasions. Hence, psychologists and psychiatrists often employ all four methods in the treatment of a single patient.

In general, however, the incompatible-response method appears to be the most widely useful and the most reliable. It is suitable for the treatment of virtually any type of habit. It has the further advantage of including, as an intrinsic part of the method, a definite plan for the production of the indispensable inhibiting reactions. Its principal drawback is the difficulty often encountered in finding a new reaction which is desirable and which can be made sufficiently strong to overcome the habit.

The exhaustion method is best adapted for the treatment of reactions which can be exhausted through repetition with a reasonable degree of probability and within a reasonable length of time. Hence it is better suited for the elimination of intense emotional responses, for

example, than for the abolition of undesirable habits of thought Moreover, as we have pointed out, the practice of this method usually is fraught with certain dangers, and the occurrence of the necessary reconditioning can in no sense be guaranteed The toleration method is used primarily for the elimination of undesirable negative or avoiding responses, such as fears, aversions, and the like The principal hindrance to the use of this method is the difficulty of controlling the intensity of the stimulus for the habit When the stimulus intensity can be suitably regulated, however, the method is usually a desirable one As to the change-of-environment method, we already have pointed out that to bring about the necessary changes in the environment in which the person lives often is not feasible, and that to move to a new environment can never in itself be depended upon to effect a permanent cure

There are methods, other than those which we have described, for eliminating undesirable habits However, our account of these four methods may be regarded as illustrative of the manner in which psychologists, especially those of the objective school, commonly view the problem Many special books and treatises are available on psychotherapy and on various aspects of the psychology of learning of which habit elimination is a part It is to such sources that those who desire further information should refer

CHAPTER XX

CONFLICT AND EXPERIMENTAL NEUROSES IN CATS

Introduction

One of the most important types of research in the fields of animal and abnormal psychology is the investigation of the effects of conflict on animals, with particular emphasis on the appearance of abnormal behavior This abnormal behavior frequently reaches the degree of "experimental neurosis," a term which means behavior disturbances, produced in an animal by experimental procedures, which resemble the symptoms of human neuroses

The significance of this type of study to psychology and psychiatry is evident Controlled experimentation enables us to find out what kinds of situation will bring about behavior disorders in animals Since human beings are similar to dogs, rats, pigs, sheep, goats, etc, in many important respects, such discoveries may be of aid to us in understanding the causes of similar disorders in ourselves

The first investigator to produce an experimental neurosis was Pavlov [1] In the study most often cited, a dog was repeatedly shown a luminous circle, immediately following which it was always fed It also was repeatedly shown a luminous ellipse, after which no food was ever given It soon mastered the required discrimination, learning to salivate (and get ready for food) whenever it saw the circle, and not to salivate, to remain "indifferent," whenever it saw the ellipse Then the experimenter presented a series of ellipses, in which the figures became progressively more and more like circles Eventually the figure became too ambiguous for the discriminative capacity of the animal The dog became unable to react to it either as to a circle (and thus a food signal) or as to an ellipse (and thus a stimulus for a negative response) Furthermore, the dog was held on a platform by a harnesslike contrivance, so that no escape from the predica-

[1] Pavlov, I P *Lectures on Conditioned Reflexes* New York, International Publishers, 1928

ment was possible. A "breakdown" now occurred. The dog, hitherto docile and quiet, began to squeal, struggle, bark, and bite. Moreover, this behavior persisted, so that when it was later brought back to the laboratory situation it again reacted in this "neurotic" fashion.

Other experimenters have obtained similar results with many other species of animals. For example, Anderson and Liddell[1] and Anderson and Parmenter[2] have subjected sheep to situations such as the following. Like Pavlov's dog, the animal is held in a constant position on a platform. The stimuli used are metronome beats, at two different frequencies. When the metronome rate is 120 per minute an electric shock is given to a foreleg; when the rate is 50 per minute no shock is given. The sheep learns to withdraw its foreleg when it hears the faster rate and to remain quiet in response to the slower one. Then the animal is subjected daily to such pairs of rates as 120 and 60, 120 and 72, 120 and 84, 120 and 92, 120 and 100. Eventually the discrimination of the sheep breaks down, just as did the discrimination of Pavlov's dog, and, like the dog, the sheep is unable to escape from the experimental situation. The result is, as in the case of the dog, an experimental neurosis. The nature of the behavior disturbance varies greatly in different sheep (and also in different pigs, goats, dogs, etc.). In the laboratory, the disturbance usually involves fear, struggling, irritability, and "nervousness," and may include a loss of excretory control, rigidity or spasmodic movements of the reacting leg, and various other abnormal responses, *e.g.*, increase of respiration and heart action. In addition, "neurotic" behavior may be exhibited outside the laboratory. This behavior may include such reactions as jumping and trembling at a slight touch or a sudden noise, general shyness and timidity even toward other animals, insomnia, disturbances in breathing and heart action and, in the case of one male dog, absence of any sexual response to a female in heat.

The current explanation of these results involves the concept of conflict and its effects upon behavior. In the training situation the animal learns to make a specific kind of response to one stimulus, and a different, antagonistic response to another stimulus. Accurate discrimination between the two stimuli is necessary for this learning.

[1] Anderson, O. D., and H. S. Liddell, Observations on Experimental Neurosis in Sheep, *Archives of Neurology and Psychiatry*, 1935, vol. 34, pp. 330–354.

[2] Anderson, O. D., and R. Parmenter, A Long-term Study of the Experimental Neurosis in the Sheep and Dog, *Psychosomatic Medicine Monographs*, 1941, vol. 2, Nos. 3 and 4.

Then in the neurosis-producing situation, the animal is subjected to stimuli which are so similar to both the training stimuli, or so similar to each other, that it is unable to discriminate between them. Therefore the stimuli tend to arouse both of the antagonistic reactions. But both of the responses cannot appear, *e.g.*, an animal cannot both escape and remain quiet. A conflict between the opposed reactions develops. Emotional disturbances occur, and if the animal is repeatedly presented with the conflict-producing situation, neurotic behavior finally appears.

In studies of the kind so far described, however, the means by which the experimental neurosis was produced may seem rather different from the causes of neurosis in human beings. To be sure, conflict seems to be an indispensable factor in both cases, a conclusion which is derived from the controlled experimentation with the animals and from analytic, clinical study of human cases. But in the animals the conflict usually has occurred between two fairly simple responses, such as *salivation* versus "*indifference*," or *leg withdrawal* versus *remaining quiet*. In human neurotics, by contrast, the conflicts typically appear to be between *major human motives, between whole areas of behavior associated with such motives and their goals*. Also, with the animals, the conflict usually has developed because of inability to discriminate between two external stimuli. In human cases, however, the person's difficulties do not commonly arise from inability to discriminate. Instead they derive from inability to resolve conflicts between powerful antagonistic motives, *e.g.*, between socially tabooed sexual impulses and moral considerations, between love for a father and hatred of him, between a need for prestige and a fear of failure. Finally, the experimental animals usually have been placed in very confining situations in which their movements have been greatly limited by harnesses and similar devices, whereas the human neurotic is not subjected to such external restrictions, and moves and acts with relative freedom in his ordinary environment.

A kind of experimental situation with animals which would more closely resemble the conditions productive of human neuroses therefore would have to meet the following requirements: (1) the conflict would have to be between two strong drives or motives, as between hunger and fear, (2) the conflict would have to be based on factors other than inability to discriminate, and (3) the animal's responses

would have to be reasonably unrestricted (although complete escape from the laboratory situation of course could not be allowed) Maier[1] with rats and Masserman with cats have performed several experiments which apparently fulfill these requirements Masserman's experiments were selected for detailed report in this chapter because both his study of external frustration (i e, the blocking of goal-seeking behavior by an external obstacle) and his investigation of various curative methods are in many respects unique, and of major interest to students of abnormal behavior and its treatment

EXPERIMENTAL NEUROSES IN CATS[2]

PURPOSES

The principal aims of Masserman's experiments were (1) to observe the effect of external frustration upon the behavior of cats, (2) to study the effect of conflict, especially in connection with the development of experimental neuroses in these animals, (3) to investigate the effect of certain variations in experimental conditions upon the neurotic behavior, and (4) to ascertain the curative value of several kinds of therapy or treatment

SUBJECTS

The subjects of the experiments to be reported were 82 cats

APPARATUS

The apparatus used is shown in Fig 36 The cage, in which the cat was placed for the experiment, measured 40 by 20 by 20 in and had a sliding door and two top hatches for the entry of the animal Its side walls and top were of glass, its floor was an iron grid The fan at the right provided ventilation In the middle of the floor there was an "escape" platform on which the cat could take refuge if the grid was electrified In the box there was a glass barrier, framed in wood, which could be moved to the left or right by the cords which can be seen emerging at the upper right-hand corner of the cage In this way the cage could be divided into two compartments of any desired size There were spaces between both the front and the back

[1] Maier, N R F *Studies of Abnormal Behavior in the Rat* New York, Harper, 1939

[2] Adapted from Masserman, J *Behavior and Neurosis, an Experimental Psychoanalytic Approach to Psychobiologic Principles* Chaps II and IV Chicago, University of Chicago Press, 1943

of the barrier and the corresponding walls of the cage These two spaces usually were blocked, however, they might be left open, in which case the cat could pass freely between the two compartments Also the glass of the barrier might at times be covered with an opaque
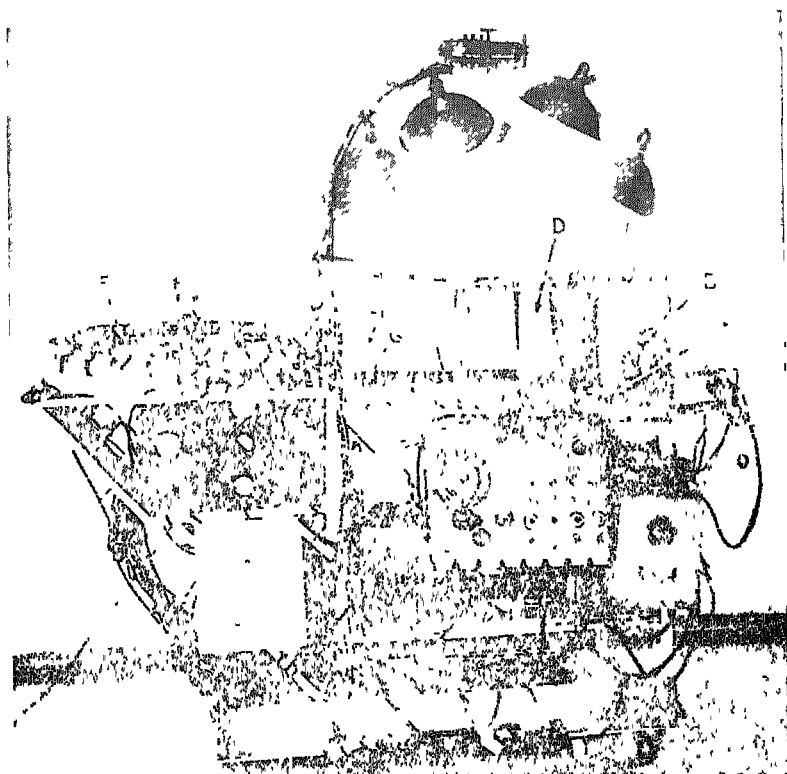
Fig. 36 Masserman's Apparatus for His Investigation of Experimental Neuroses in Cats

A iron grid *B* fan, *C*, escape platform *D* glass barrier, *E*, disk control switch, *F*, rotary feeder with cups *G*, food box, *H* hinged lid of food box (*Reproduced by permission of the University of Chicago press*)

screen so that the cat could not see from one compartment to the other On the floor at the extreme right of the cage just below the ventilating fan there was a disk-control switch This the cat could learn to press and thereby activate the signals and the rotary feeder described below

To the left of the cage there was a rotary feeder, provided with numerous cups containing food Inside the cage, at the extreme left,

there was a food-box with a hinged lid (shown raised in the figure) The apparatus was so contrived that when desired, e g , at the production of the feeding signals, the feeder would rotate until one of the food cups was directly opposite the food-box The cup would then be tripped and its contents poured through a funnel (not visible) into the box

On the arch above the cage there were lights of various intensities, together with bells and buzzers These provided the feeding signals

In the lower rear left-hand corner of the cage there was an air vent (not visible) which when opened threw a blast of air across the food-box Both the grid floor and the escape platform could be made to provide an electric shock to an animal in contact with them

The various other parts of the apparatus not specifically noted above were designed and used for the automatic production of the various signals, the air blast and the electric shock, and for the movement of the rotary feeder In addition a motion-picture camera was used to photograph the subjects at appropriate times Some of these photographs are reproduced in Fig 37

THE DEVELOPMENT OF CONDITIONED FEEDING RESPONSES

In order to investigate the effects of frustration and conflict on the behavior of cats, it was first necessary for them to learn the behavior which was to be frustrated, or subjected to conflict-producing situations This learned behavior consisted of "conditioned feeding responses" Two different conditioned responses were established in all the cats, and a third type was developed in many of them These responses, and the methods by which they were established, were as follows

1 The cat first learned to associate the feeding signals with the delivery of food into the food-box These signals usually were the simultaneous occurrence of a light flash and a ringing bell, which lasted for about 2 sec To establish this conditioning, the cat was first accustomed in its living cage to a daily ration of a specific type, namely, a mixture of solid "Kiblets," "Ideal" dog food, and salmon After 24 hr without food it was put in the experimental cage, the lid of the food-box was opened, and the familiar food placed in it The cat learned almost at once to eat its ration from the food-box Then, sometimes on the third experimental day the feeding signals were

given and—at the same time or a second or so later—some food was put in the box. The cat learned quickly—in one case in 12 trials—to go to the food-box (the lid of which was always open) when the feeding signals were presented, and get the food or wait briefly for it.

2. The cat next learned to open the food-box when the lid was down by raising the lid with its head or paw. This response was developed by having the lid put lower and lower on successive signal-accompanied feedings. The cat thus gradually learned to get at the food by lifting the lid, at first a little, then more, until finally it could lift it from its fully shut position. Now the animal, in response to the light and sound signals, would at once go to the food-box, raise the lid, and get the food. An additional stimulus for the animal was provided by the sound of the movement of the rotary feeder, which was synchronized with the signals and automatically delivered the food.

By this time most of the cats eagerly jumped into the cage when allowed to do so, resisted removal from it, and seemed to wait for the feeding signals with avid anticipation. In many cases the responses were given a very large amount of practice, since the animals obtained all their food in the cage and the small size of the food cups might make 30 to 50 feedings a day necessary for the maintenance of normal weight and physical condition.

3. Many cats also learned to get food by depressing the disk-control switch, which could activate the feeding signals and the delivery of food by the feeder. This learning typically required 10 to 60 trials over a period of 1 to 6 days. In some cases the cat learned to depress the switch by accidentally rubbing against it, following which the light flashed, a bell or buzzer sounded, the feeder rotated, and food appeared in the food-box. In other cases the cat was "taught", that is, a large and conspicuous platform was put on the switch disk and the experimenter placed the animal's paw on the platform many times in succession. In other instances a small cup filled with salmon juice was attached to the disk, so that the cat would necessarily depress the switch by chin or mouth pressure while lapping the juice. The animals varied in their manner of pressing the switch, some using the paw, others the head, depending on which way of responding they had first employed. Once a cat had learned the reaction it would press the switch, go to the food-box, eat as much as it could get from it, return to the switch, press it again, and so on until the feeding was stopped or the cat was satiated.

After the cats had acquired these two or three "conditionings," they were ready to be tested for the effects of external frustration and of conflict

THE EFFECTS OF EXTERNAL FRUSTRATION

An important section of Masserman's experiments deals with the effects of external frustration upon the behavior of cats As we have said, external frustration means the blocking of goal-seeking behavior by an external obstacle In the present instance the goal was to feed in the food-box The principal external obstacles employed are described below

1. Presence of a Barrier. In some cases the glass barrier was placed in such a way that the food-box was on one side of it while the cat was on the other, able to see the box but unable to reach it When the feeding signals were given and the food was deposited in the box, the animal clawed at the barrier, mewed, and paced about However, it gave no evidence of anxiety, fear, or conflict, and after about 8 to 20 trials stopped responding at all to the signals (experimental extinction[1])

2. Closing of the Food-box. Another external obstacle was provided by locking the lid of the food-box This procedure was used with 12 well-trained cats Typical reactions were scratching and prying at the lid following the feeding signals After a few trials—in two cases, seven trials—the animals simply stopped responding to the signals (again, experimental extinction) No neurotic behavior was ever produced

3. Failure of the Control Switch to Function. Still another kind of external frustration was used with some of the cats that had learned to manipulate the control switch The current was turned off, so that pressure on the switch was no longer followed by the feeding signals The animal became markedly disturbed, refusing to feed, mewing almost continually, pacing about, energetically pressing on the switch, and even attacking it with teeth and claws Nevertheless, no actual neurosis developed, and when the current was restored the cat at once resumed its normal behavior

[1] "Experimental extinction" means the elimination (often only temporary) of a conditioned reaction by repeated presentation of the conditioned stimulus (here, the feeding signals) without reinforcement by the unconditioned stimulus (here, accessible food in the food-box)

4. Irregular Feeding. Eight cats were subjected to the partial frustration produced by irregular feeding, that is, sometimes food would appear in the food box following the signals and sometimes it would not Under these circumstances some restlessness was observed, but there was no evidence of any marked disturbance, and the normal reaction to the signals persisted even though it was often quite unrewarded

DISCUSSION

So far as Masserman's cats are concerned, the results of the frustration of feeding behavior by means of external obstacles were definite and consistent The most frequent effect of such frustration was to bring about an adaptive cessation—a temporary extinction—of the food-getting responses No behavior that could be called "neurotic" was ever produced by it It is uncertain to what degree one can draw analogies between these few cats in these specific laboratory situations and human beings in the complex vicissitudes of their daily living However, the negative results of external frustration in this experiment contribute some additional support to the belief, widely held by psychologists and psychiatrists, that external frustration alone does not commonly produce "mental" disorders, that human beings do not usually break down merely because external (environmental) obstacles block them from obtaining the money, prestige, sexual satisfaction, etc , that they desire, and that for frustration to be causative of neurosis, goal-seeking behavior must be blocked through internal sources, typically by some sort of internal conflict Thus if a young man's proposal of marriage meets with rejection—which is here the external obstacle—although he may be deeply affected, he does not commonly develop a neurosis, but if his sexual desires are frustrated by an internal struggle between them and fear of the opposite sex, a "breakdown" frequently results

THE EFFECTS OF CONFLICT THE PRODUCTION OF EXPERIMENTAL NEUROSIS

Masserman produced experimental neuroses in his animals by a very simple method After a cat had learned to secure food in the food-box in response to the feeding signals, it was subjected to an air blast, a grid shock, or both, *at the moment of feeding*

The air blast was delivered across the food-box just as the cat opened

the lid or was about to feed The blast usually lasted 1 to 2 sec The typical reaction in 52 of the 58 cats subjected to this stimulus was a sudden rush to the far side of the cage and a crouching there the behavior being suggestive of intense fear The animal usually refused to make any further attempt to feed in spite of the repetition of the feeding signals and the presence of food in the box This fear response seems to be an unlearned or reflex reaction in the cat (However, six animals reacted less vigorously than the others They cowered only momentarily, withdrew only slightly from the food-box, and soon began to reexplore the latter)

The grid shock, delivered through the floor of the cage to the animals' feet, was used with 24 cats, and also was given at the moment of feeding Usually two or three shocks were given in rapid succession The typical response was a startled jump at each shock, followed by a slow retreat from the food-box after the shocks ended In other cases the cat would remain for a time near the box in a crouched position with tensed muscles, closed eyes, and curled paws Occasionally the shock produced the same "precipitate scramble" as the air blast did, and eight animals were so excited by it that they dashed about the cage seeking escape Some snarled, mewed, and yowled also Feeding of course ceased entirely in every case Seven cats were given an opportunity to avoid the shocks by going to the escape platform and quickly learned that response

Twenty-four cats were subjected both to the air blast and the grid shock Their reactions resembled those to the air blast alone

Thus far the typical result of these procedures has been as follows The cat, having been subjected, at the very moment of feeding, to stimuli that are terrifying, painful, or both, has stopped its food-getting responses and exhibited marked fear behavior In spite of its hunger, the continued presentation of the feeding signals, and the presence of food in the food-box, it refuses to make further attempts to eat and persists in its fear responses

Eventually the cat was removed from the cage, and its first conflict-producing experience was over Twenty-four hours later it was again placed in the cage It now had eaten nothing for two days, since, as was stated earlier, all feeding took place in the experimental situation Many cats now responded to the feeding signals with the fear behavior they had shown during their initial experience with the air

blast or shock If a cat made any attempt to feed normally, the air blast or shock was repeated with the behavior effects already described In either case the cat again was removed from the cage, and after another 24 hr was returned again to it Now, in spite of its extreme hunger, the fear behavior almost always recurred without further stimulation and the cat would eat nothing

Aside from the fear and the refusal to eat in the cage described above, these blast and shock experiences also produced an experimental neurosis It may be presumed that a severe conflict was brought about in the animal On the one hand it was hungry, often extremely so, and food was there for the taking by means with which the cat was thoroughly familiar On the other hand, it feared the blast, the shock, or both Thus the animal in the cage was simultaneously under the stress of the two incompatible motives of hunger and fear, and was simultaneously impelled to the incompatible actions of feeding and escape In a sense it was driven to make two antagonistic responses at one and the same time, much as a human being is when fear competes with anger, or with sexual desire, or with a sense of duty

In almost every cat one or two such experiences were enough to produce some sort of "neurotic" behavior The symptoms shown by different animals varied greatly in kind, in degree, and in the number of stimuli which would elicit them Some animals showed *changes in spontaneous activity*, *i e*, previously quiet, placid cats tended to become restless and "nervous," while previously active ones tended to become passive and inert, lying immobile in the cage for long periods Many displayed *chronic anxiety*, both in the cage and outside it They were restless, trembled frequently, often crouched or hid themselves, gave startle reactions to minor stimuli in the environment, and showed recurrent or chronic disturbances of pulse and respiration *Phobic responses* also were very common In the experimental cage the cats usually reacted to the feeding signals with fear amounting to panic, and with efforts to escape which sometimes became frantic Animals that had learned to use the control switch often avoided it, as if it had become dangerous, or "ignored" it, behaving as though it were not in the cage at all Others continued to press it, but would make no attempt to get the food Some starved themselves into a condition of severe weakness and malnutrition, even
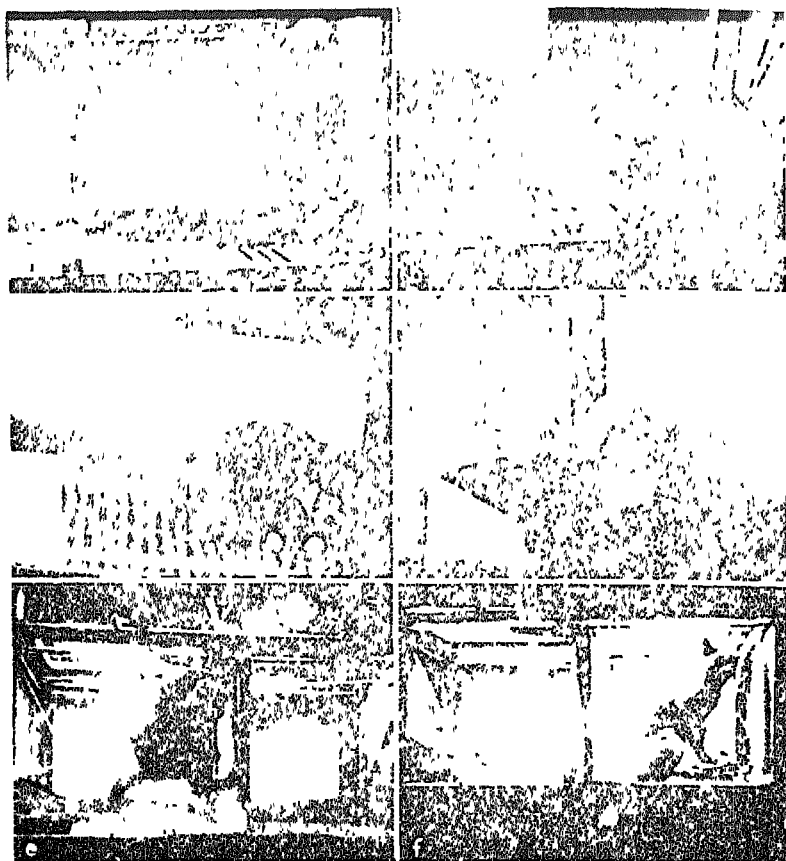
FIG 37 Examples of Various Types of Neurotic Behavior in Masserman's Cats

a A marked fear reaction in a cat prevented from escaping from the cage The animal showed erection of the hair and a considerable pupillary dilation

b Continued refusal of nearby food by a cat which has starved itself for two days

c A cat snarling at the signal for food

d Hiding the head in the food box in response to the feeding signals Despite several days of starvation the animal remained fixed in this position for from 5 to 10 min without touching the food in the box

e Marked fear reaction accompanied by frantic attempts to escape, made by a hungry cat kept close to the food box by the movable barrier The food signals are being given

f Persistent pressing of the switch which activated the feeding signals, but with no attempt to walk around the barrier and get the food (*Reproduced by permission of the University of Chicago Press*)

though food was in the cage and readily available One cat would not feed in the cage for 16 days, though given only one-tenth of its normal ration outside the cage, and thus lost one-third of its weight Some animals developed a kind of generalized fear of food and of eating

They would eat very little food anywhere, in or out of the cage, or would eat only food different from that provided in the cage, or food given them by the experimenter's hand *Stereotyped nonadaptive responses*, often of a peculiar nature, were exhibited by some animals An example is that of a cat that ran to the food-box, put its head under the lid, and remained fixedly in this position but without eating in spite of many days of starvation Another cat crouched in a fixed position behind the food-box on the side of the air blast Many animals showed what Masserman calls "regressive behavior,"[1] that is, responses assumed to be more characteristic of earlier periods in their lives Thus some cats became unusually playful and affectionate, like young kittens, and seemed to want to be petted and fondled Others seemed to lose their tameness, becoming aggressive and vicious and attacking their cage mates and even anyone who offered them food Many animals exhibited several kinds of symptoms, either simultaneously or at different times during their "neurosis" Some of these and other neurotic reactions are shown in Fig 37

The above brief description shows that the cats developed behavior which was definitely abnormal and maladjustive when compared with their previous well-adjusted reactions, and which also was similar to that commonly observed in human neurotics

It should be noted that these neurotic reactions were not just ordinary fear responses to the air blast, and apparently were not due to the fearsome qualities of the blast alone In a control experiment, six cats were subjected repeatedly to the air blast without any connection with feeding All of these animals quickly became accustomed to the blast and ceased to show their initial fear Also, the effects on the cats in the main experiment went beyond those characteristic of ordinary fear reactions, especially in that they were not confined to stimulation by the blast itself but pervaded the animal's whole behavior

FACTORS TENDING TO ACCENTUATE THE NEUROTIC BEHAVIOR

Two factors were found to accentuate the neurotic behavior One was an increase of hunger to the point of about 72 hr of starvation It will be remembered that normally the cats were fed only in the ex-

[1] It is possible that, from a strictly factual viewpoint, this "regressive behavior" consisted only in a change of emotional responses on the part of certain cats

perimental cage, and that after they had undergone the fear experience and had refused to eat there, they were brought back on later days for repeated observations It was found that up to and including the third day, as their hunger increased, their behavior grew increasingly disturbed also, until on the third day, when they had been without food for 72 hr, it usually reached a kind of climax After this third day many animals had to be given small feedings outside the cage to maintain health and life In other cases, further starvation apparently produced such an accentuation of the hunger drive that the fear was overcome and, if no further "punishment" was given, the cat began to eat again in the cage This result is described in connection with the curative procedures discussed below

Another factor which accentuated the neurotic behavior was restriction to a small space in the cage This restriction was readily accomplished by moving the barrier to the left (see Fig 36e) and putting the cat in the compartment thus created, a space which was not only very small but which also contained both the food-box and the place where the air blast or shock had been experienced Sometimes the glass barrier was made even more confining in its effect by placing the opaque screen over it In this situation the feeding signals usually brought about more violent clawings and attempts to escape than any that had been shown previously

Both of these experimental procedures augmented the stress to which the animal was subjected, by increasing the intensity of its hunger in the one case, and the intensity of its fear in the other The effects resemble those which might be produced in a human conflict situation if the intensity of one of the motives involved, such as sexual desire, hatred, or fear, became strengthened However, as the results of Masserman's curative methods will show, if the intensity of a drive or other motivation is increased sufficiently, it may bring about such overt action as will break the impasse and terminate the conflict

Methods of Alleviating Experimentally Induced Neurotic Behavior

An interesting and valuable part of Masserman's experiments is his use of various procedures designed to alleviate or "cure" the experimental neuroses, and his observations as to their effectiveness These methods resemble in many ways those employed with human neurotics, and in a sense may be regarded as methods of "psychotherapy"

One method was that of *rest* Thirty-seven neurotic cats were re-

turned to the experimental cage after "rest periods," *i.e.* absences from it and the fears and conflicts it had induced, of from 2 weeks to 5 months Thirty of these animals displayed almost the same neurotic reactions as before to the feeding signals and to the cage in general, refusing to feed there and still showing marked fear In seven cases however, a "prolonged" rest did result in some alleviation of the neurotic behavior, the cats seemed less afraid, and sometimes ate a little in the cage The failure of the rest method for the great majority of the subjects with which it was used has considerable psychological interest In general, it indicates that reactions once formed tend to persist unless definite reconditioning processes like those described in Chap XIX have taken place in the meantime Other experimenters working with other species of animals similarly have found that rest, in the sense of absence from the conflict situation, was of little or no curative value In some instances the neurotic behavior has even been more pronounced after such a "vacation"

Another method was *reduction of the hunger drive* If a cat was fed just before being placed in the cage, it usually showed diminished neurotic behavior The explanation seems to be that reduction of one of the antagonistic motives lessened the conflict However, few if any animals were actually cured by this means

A third method is termed *reassurance* and *persuasion* In this procedure a neurotic cat might be induced to eat from the food-box by handling, stroking, and petting by the experimenter However, the cat tended to remain dependent on the latter, and might stop feeding the moment the experimenter's hand was withdrawn Also, this kind of "therapy" could not be used if the animal had become distrustful or fearful of human beings

Another method was that of *forced solution*, in which the intensity of the cat's desire for food was increased to such a degree that the food-getting reactions came definitely to prevail over the fear behavior At first it was thought that this method required only that the cat not be fed at all outside the cage, the assumption being that its increasing hunger eventually would compel it to eat from the dreaded food-box Actually, however, the intensity of the animal's hunger seemed to diminish from the third day on,[1] and many cats refrained from eating

[1] It is interesting to note that according to Cannon stomach contractions and hunger pangs cease in human beings after a few days of complete fasting (Cannon, W B *Bodily Changes in Pain, Hunger, Fear and Rage*, New York, Appleton, 1915)

for such long periods that only forced feedings outside the cage kept them alive Hence, for most of the cats treated by this method, the intense hunger had to be combined with other stimuli highly conducive to eating Among these stimuli were providing very attractive food, including catnip, in the food-box, keeping the lid of the box open so that the food in it was clearly perceptible, and forcing the animal close to the box by using the glass barrier in the manner already described Under such conditions most cats finally started to eat, at first in a very hurried and fearful way, later in an increasingly normal fashion

A fifth method was *social example*, that is, the effect of seeing the normal feeding behavior of a nonneurotic cagemate This method was tried with nine animals, each of which was placed in the cage with its normal mate and saw the latter get food in response to the signals The results were highly variable Some cats learned to feed normally again after such an experience, whereas others were quite unaffected by it and remained as neurotic as before

A final method was one involving *partial control of the situation* by the animal subject This procedure could be used only with those cats that had learned to manipulate the control switch When these animals were exposed to the blast or shock, they developed neurotic behavior like the others, though usually in a milder form However, their ability to control the production of the feeding signals themselves (by pressing or not pressing the switch) seemed to give them a marked advantage over the other animals Usually, with or without the stimulus of increasing hunger or spatial constriction, they would begin spontaneously to approach the switch again, to reexplore it, and finally to manipulate it once more Then, with behavior that suggested increasing self-confidence, they reestablished their former normal behavior and their neurotic reactions vanished This sixth method was the most effective of all

It is noteworthy that once the cat was "cured," the air blast which had occurred at the moment of feeding—but apparently not the electric shock—might become an "eagerly awaited signal for feeding," a remarkable reversal of response which testifies to the malleability of cat behavior [1]

[1] It should be pointed out that Masserman did not use the same procedure with all his animals As we have said, some learned to manipulate the switch control, others did not Some, but not all, were subjected to external frustrations and to conditions intended to

Masserman is not the only psychologist who has experimented with various curative procedures for neurotic animals For example Anderson and Parmenter,[1] using sheep as subjects, tried such methods as rest, which was not particularly effective, making the problem (in this case, one of discrimination) easier, using various drugs and hormones (which varied in their effects but in general were of little value), etc Possibly, however, Masserman has explored the therapeutic possibilities of psychological (reconditioning or retraining) methods with animals more thoroughly than most other investigators

Although no one can infer directly from these results with cats what methods would be most effective for the treatment of disturbed human beings, certain comparisons seem possible The slight value of *rest* for cats, for example, appears to have some analogy with its similarly dubious effectiveness for human beings (See the discussion of the change-of-environment method in Chap XIX) As is generally known, *reassurance and persuasion* of a verbal type are extensively used with human cases Usually, these devices are more likely to make a patient feel better, to relieve his symptoms for a time, than they are to cure him However, as reference to Chap XIX will show, reassurance and persuasion may play the role of S^2 in the "incompatible-response" method The *forced solution* method also has its analogies in human psychotherapy It resembles somewhat the "exhaustion" method of reconditioning also described in Chap XIX Its effects also are like those of an inescapable emotional or other crisis, or a huge accentuation of some drive or dominant motive, which sometimes seems to force a behavior change in the human patient The *social example* method is likewise similar to conditions which may benefit human subjects Thus, as Masserman points out, civilians made

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accentuate neurotic behavior For the production of an experimental neurosis, the air blast alone was used with some animals, with others the grid shock or a combination of blast and shock After a neurosis had been established, both the kind of curative method and the exact way in which it was used varied considerably with different animals Many cats were treated almost as if they were human cases, in the sense that several types of therapy were tried with them and tests of their value made Hence it is impossible to express the results of the many experiments in tabular or statistical form In addition, Masserman does not always state the exact numbers of animals that were subjected to the various experimental procedures, nor does he give such data as the average numbers of trials required for the establishment of the three conditioned responses, for the development of the neurotic behavior, etc

[1] Anderson and Parmenter, *op cit*

temporarily hysterical during a bombing raid were helped to recover by seeing their more stable fellows going about their work with relative calmness The last method of Masserman, in which the animal could *exert some control over the situation*, could "work through" it himself, seems to be an excellent device whenever it can be applied Masserman compares it to the behavior of the airplane pilot who forestalls a neurotic breakdown after his plane has crashed by at once flying another plane and thus reasserting his "accustomed and reassuring mastery " Indeed, the method is similar to the creation of any circumstances which allow a person some control over conflict situations The stutterer would have much less difficulty with his speech, might in fact be able to reduce or eliminate his disorder, if he could himself choose just when he would speak, to whom he would speak, and what he would say

Summary and Conclusions

Masserman's work shows that experimental neuroses can be readily produced in cats by subjecting them to a situation which brings about a conflict between two presumably powerful motives, hunger and escape from terrifying or painful stimulation A conflict of this type seems to resemble closely the conflicts basic to human neuroses, such as those between sex urges and moral considerations, between fear in a soldier and his sense of duty to his unit, between resentment toward one's parents and affection for them The relationship shown to exist in cats between conflict and neurosislike behavior adds further cogent support to the principle that conflict probably is an essential factor in producing functional mental disorders, *i e* , disorders of behavior not attributable to organic brain damage, infections, toxins, and other physiological agencies [1]

Masserman's finding that external frustration alone did not produce any neurotic disturbances is of special interest Many students of mental disorders have long agreed with Freud[2] that although frustra-

[1] A somewhat different explanation of the behavior of both Masserman's cats and of human neurotics is given by White, who believes that the essential factor in producing neurosis is not conflict, but fear or anxiety and the efforts to diminish or eliminate it and prevent its recurrence See White R W *The Abnormal Personality* New York Ronald, 1948

[2] Freud, S Types of Neurotic Nosogenesis In *Collected Papers*, vol 2, pp 113-121 London Hogarth Press 1921

tion in the sense of the blocking of strongly motivated behavior is essential to neurosis, the blocking must be due to conflict, must come from internal sources. The present experimental results appear to bear out this view, as we have seen.

As we have pointed out, the various curative methods which Masserman employed are similar in many ways to those used with human beings. The failure of rest to "cure" the abnormal behavior, and the success of forced-solution and partial-control methods are especially noteworthy. Of course Masserman could not try all possible procedures, and did not experiment specifically with the toleration, exhaustion, and other methods described in Chap. XIX. In this connection it might be noted that Masserman has recently tried still other kinds of treatment with neurotic cats, notably the administration of alcohol[1] and cerebral electric-shock therapy.[2] Lack of space prevents us from saying more than that as a rule both of these procedures were successful.

Psychologists and psychiatrists have long been interested in the production and study of abnormal behavior in animals, and this kind of research is certain to continue. One reason for the general belief in its importance is the significant advances in our knowledge and control of various physical diseases which have resulted from experimental work with animals. The utmost value may accrue to the discovery of animal species which are susceptible to human diseases, and which therefore can be utilized in controlled experimentation designed to discover the causes of a particular disease and methods of treating it. Observations made upon cows were of vital importance in the discovery of vaccination as a preventive of smallpox; experiments with dogs contributed greatly to the discovery of the specific cause of diabetes and of the insulin treatment. Similarly, in the psychological realm, in the field of functional mental disorders, our ability to create what seem to be analogous disturbances in animals amounts to a genuine scientific achievement. Our understanding of the causes of human disorders already has materially benefited from

[1] Masserman, J. H., and K. S. Yum. An Analysis of the Influence of Alcohol on Experimental Neuroses in Cats. *Psychosomatic Medicine*, 1948, vol. 8, pp. 36–52.

[2] Masserman, J. H., and M. G. Jacques. Effects of Cerebral Electroshock on Experimental Neurosis in Cats. *American Journal of Psychiatry*, 1947, vol. 104, pp. 92–99.

these investigations, and the further testing of various therapeutic methods with animals may greatly facilitate our search for the most desirable procedures to be used with human beings. Certainly psychologists and psychiatrists will neglect no promising source of helpful evidence in their efforts to deal with the tremendous personal and social problems created by mental disorders in modern society.

CHAPTER XXI

PROBLEMS IN THE PERCEPTION OF THE VERTICAL IN SPACE

INTRODUCTION

The subject of perception, which involves the study of the organized impressions we form of the world around us, deals typically with phenomena that every person has often experienced Such phenomena are exemplified by our perception of the vertical and the horizontal Usually we are able to identify these main dimensions of space with accuracy Almost from moment to moment we make judgments about the position of surrounding objects and of our own bodies which indicate an effective mastery of the location of the true vertical in space Nearly always we can tell readily and without deliberation whether or not a picture on the wall is straight, whether the road on which we are walking has a slope or is level, or whether we are leaning backward or forward when sitting in a rocking chair These operations in the perception of space are so smooth-running and reliable that they occasion little notice in everyday life It is only when something goes wrong" that it becomes difficult to tell whether we are right side up or not This may happen at times during an airplane ride, or in such amusement-park devices as the roller coaster or the "haunted swing "[1]

The capacity to perceive the vertical and the horizontal is basic to our everyday dealings with objects in the environment and to the 'handling" of our own bodies Experiments designed to discover how this kind of perception takes place may therefore cast light on pro-

[1] In the "haunted-swing situation" studied years ago by Wood in connection with problems in space perception, the subject is strapped into the seat of a chair suspended from a horizontal bar running the length of a large barrel-shaped canvas room He believes that the "swing" is to be set in motion, but instead, the canvas room is turned forward and backward through a limited distance as though it were an oscillating drum Under these conditions there results a most compelling illusion that the "swing" itself is being moved back and forth and that the room is stationary (Wood, H S The "Haunted-swing" Illusion *Psychological Review*, 1895, vol 2, pp 277-278)

cesses which are vitally necessary to our effective everyday perceptual adjustments

For one thing we find in the perception of the vertical and horizontal a striking example of what is known as "perceptual constancy" The meaning of this term is readily illustrated by the fact that one can tilt his head, lie on his side, or even stand on his head without having the walls of the room and objects in the room cease to appear "upright" while these postural changes are occurring A moment's consideration will show that what happens in such cases is far from simple Actually tilting the head causes reflected light from objects to be projected upon the retina at very different angles than is the case when the head is erect Notwithstanding such changes in the specific stimulative effects provided by surrounding objects, these objects continue to retain their upright character for the perceiver It is in this sense that such phenomena are said to exemplify "perceptual constancy"

There is another problem of general psychological importance which is involved in studying perception of the vertical and horizontal Perception of this aspect of the environment depends not only upon vision but also to a great extent upon the stimulation of several other types of receptors, such as the kinesthetic and the static Furthermore, the fields of sensitivity involved do not usually function separately but rather as a total system in which the parts are closely interrelated and form organized patterns The integration of different types of sensory impressions plays a far more prominent role in space perception than in cases such as color vision which involve only a single sense modality

Let us consider further the statement that perception of the vertical and horizontal depends upon the integration of several different kinds of sensory stimuli Basically these stimuli fall into two main categories, the visual and the postural Now "space," as it is visually perceived, may be described as having a frameworklike composition, the main axes of which are set by the vertical and horizontal directions This "framework" was described by the late Max Wertheimer, a noted Gestalt (or "configurational") theorist in psychology, as an organized, patterned visual field distinguishable from the postural and the more subjective factors influencing perception In this "field" the separate components (*e g* , the vertical and horizontal lines in a given situation

as furnished by the corners of walls and floor in a room) have a combined patternlike effect attributable to their presence together in a system under given conditions

The verticals and horizontals which abound in almost every situation provide us with a "standard" against which the position of any object—including one's own body—may be perceived In addition to the visual basis for judging the vertical and horizontal, the gravitational pull on the body, a force which corresponds in direction to the true vertical (*i e* , to the drop of a plumb line) provides a further basis for judgment Although normally we are not aware of the fact, the body is constantly adjusting itself to this pull, and the sensory effects that result from our postural adjustments enable us "automatically" (*i e* , without thinking about it) to determine the direction of the pull, and thereby to determine the upright Thus, with eyes closed, it is possible to determine whether one's body is upright or is tilted left or right, and any perceptual adjustment of this kind reflects an effective knowledge of the direction of the true vertical and horizontal The specific sensory data available to the mammalian organism in adjusting to gravity include kinesthetic impulses from muscles and tendons, a complex pattern of tactual impulses from the skin, and impulses from the viscera and from the semicircular canals of the inner ear

Although two main sources of "information" (visual and postural) are available for determining the vertical and horizontal in almost any situation, we do not experience two separate sets of verticals and horizontals, one visual and the other postural, which we must then somehow put together Rather, our experience is unified to such an extent that it is very difficult to determine the separate contributions of visual and postural factors to the adjustment A principal reason for its unified character is the fact that the vertical of the visual field and the gravitational vertical coincide perfectly in direction This intimate and orderly relation between visual and postural factors is invaluable in helping us to determine our own position and the position of other objects quickly and easily, and therefore aids us greatly in coping with our environment

However, the very closeness of the relationship between these two factors makes it impossible to study the problem of how we perceive the vertical (*i e* , the upright) aspect of space adequately under every-

day conditions The separation of visual and postural factors so that their characteristic individual contributions to space perception may be discerned can be accomplished only by experimental means

The investigation to be described in this chapter represents such an undertaking Some of the specific questions on which these experiments throw light are the following how is one's perception of body position and the position of the surrounding field accomplished? What is the relative importance of visual and postural factors in such perception? How is the constancy of the perceived vertical and horizontal ordinarily maintained? How do people differ in the way in which they integrate the visual and postural experiences which underlie the perception of the upright?

WITKIN'S INVESTIGATION[1]

The problem of the experiments to be reported in this chapter was to investigate the conditions which determine the perception of the upright when the position of the subject's body itself, the position of the visual field, or both of these are subjected to systematic changes

APPARATUS AND SITUATION

The subject in the present experiments was seated in a specially constructed chair within an experimental room, in a situation so arranged that either the room or the chair could be tilted to right or to left as the procedure required The tilting-room and tilting-chair setup used in this investigation is shown in Fig 38 The room was made of plywood and was 6 ft long, 5 ft wide, and 5 ft high In order that the experimenter could observe the subject at all times and speak to him when necessary, the back of the room was left without a wall The entire room was mounted on stands, with a worm-gear arrangement in the mounting which permitted the experimenter to tilt the room through a predetermined angle up to 35 degrees to either side from the true vertical, simply by turning a crank, and which also permitted the subject to tilt the chair, when procedure required

The experimental room was lighted from within by a 25-watt fluorescent lamp The outer laboratory was kept fairly dark so that no visual cues would be available to the subject from shadows outside his room

[1] Adapted from Witkin, H A Perception of Body Position and of the Position of the Visual Field *Psychological Monographs General and Applied*, 1949, vol 63, No 302, pp 1–46

In this way, effective cues for judging the upright were confined to the tilting room itself To provide a well-defined visual framework within the room, the entire inside of the room was painted gray and the
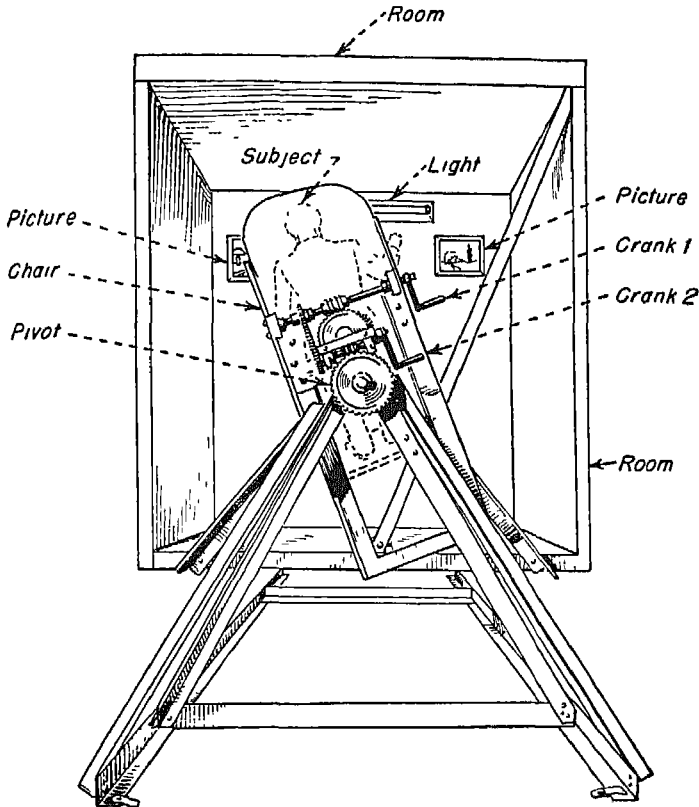
FIG 38 Sketch of the Tilting-room and Tilting-chair Apparatus as Arranged for Situation F, Series II, in Which the Room is Upright and the Subject's Chair is Initially Tilted 22 Degrees to the Left

In this test the subject (while blindfolded) is to bring the chair to a position which he perceives as "upright" The various arrangements of room and chair used in these experiments are described in the text, and those of series II are shown graphically in Fig 39 Crank 1, experimenter's crank for changing angle of chair tilt, Crank 2, experimenter's crank for changing angle of room tilt, Pivot, axis about which room and chair are turned

borders of the walls were marked boldly with white paint, also two pictures in rectangular frames were fixed to the wall in front of the subject's chair

GENERAL PROCEDURE, SUBJECTS

The subject sat in a high-backed chair which was placed in the middle of the tilting room and was provided with arm rests, foot rests, and a head rest The rests were especially important in that they served to support the body when the chair was tilted and thus constituted sources of body-pressure cues The chair was mounted on a shaft which projected into the room through its open rear With this arrangement the experimenter could tilt either the chair or the room independently through predetermined angles, or could tilt them together, by turning appropriate cranks at the open end of the room Or when the procedure required it, the subject himself could move his chair by using a crank placed near at hand in front of him The angle of tilt of room and of chair could be read by the experimenter from the position of the pointers on corresponding protractor scales placed just outside the open end of the tilting room behind the subject's chair

The subjects were 100 undergraduate students of psychology at Brooklyn College In all, there were 22 men and 78 women, ranging in age from seventeen to twenty-three years

THE EXPERIMENTS

SECTION I CHANGING RELATIONS BETWEEN BODY AND FIELD

Procedure. Tests were made of the subject's perception of his body position and of the position of the "external upright" during continuous side-to-side movement of (1) the chair (and body) alone, (2) the room (visual field) alone, and (3) both the chair and room simultaneously, in the same or in opposite directions The subject was asked to give a running account of his impressions of the room and of his body, particularly as concerned their apparent relations to the vertical When the subject happened to stop talking for any length of time, the experimenter would ask, "What is happening now?"

Results. Under *condition 1*, when the chair alone was moving, with the room stationary and upright, the situation was always correctly perceived, *i e* , the subject reported the different tilt-positions of the chair with considerable accuracy

Under *condition 2*, in contrast, radical perceptual errors occurred when the room alone moved while the chair remained stationary In such cases, an illusory body movement was experienced in a direction *opposite* to that of the room movement while the room movement

was either underestimated or was not perceived at all Thus either all or part of the changed relation between body and field, actually due entirely to room movement, was attributed to body (*i e*, chair) movement When the *entire* change was attributed to body movement, the room was reported as completely stationary, even though it had been moved from extreme right to extreme left When the change was attributed only *partially* to body movement, the subject reported some movement of the room, but referred this to some extent at least to body movement In such cases, the room was perceived as moving in the direction it was actually taking, and the body was perceived as moving in the opposite direction

Under *condition 3*, when body and field moved simultaneously but in *opposite* directions, the effect on the subject's perception was complex He perceived correctly that his body was moving in a given direction but experienced the illusion of a faster movement than actually was the case In tests under condition 3 in which body and field moved in the *same* direction, the subject also perceived correctly that his body was moving, but now the movement seemed to him to be slower than it really was

From the results obtained under conditions 1, 2, and 3, it seems clear that the perceived speed and direction of body movement depends upon whether the relation between body and field changes, and if it does, what the nature of the change is If the body alone is moved, with the field stationary, the body movement is correctly perceived If the field alone is moved, with the body stationary, an illusion of body movement occurs in varying degrees If both body and field are moved, the body movement is always perceived, but it appears to be faster or slower than actually is the case, depending upon whether the body and field move in the opposite or in the same direction Hence these tests demonstrate the important part which the "visual framework" may play in the perception of body movement [1]

[1] One of the special tests under condition 2 indicated how the illusion of movement changes in dependence upon the effective stimulative field For instance, a complete illusory body movement was much more likely to occur when the subject (himself stationary while the room moved) was instructed to look toward the floor of the room than when he looked toward the ceiling A difference in the complexity of the visual field (*i e*, the number of "reference points" in it) in the two cases evidently was responsible—*i e*, the "floor view" included glimpses of the subject's own body and of the chair and its fittings, whereas the "ceiling view" involved only features of the room itself

Under all of these test conditions there were marked individual differences in the extent to which the condition of the visual field influenced the perception of body movement. Under condition 2, in which the body was stationary and only the room moved, most of the subjects experienced a body movement which seemed so real that its illusory character was seldom even suspected. However, a few of the subjects reported no illusion of body movement at all in this situation. Similarly, under condition 3, where both chair and room actually moved, some of the subjects were more affected by displacement of the visual field than were others. There appear to be significant differences among people in their susceptibility to illusions of body movement in relation to visual perception.

Just as in many other perceptual illusions (*e.g.*, the Muller-Lyer illusion), knowledge of the actual situation does not eliminate the induced illusion, although such knowledge may reduce the effect. On certain trials under condition 2, after the subject had reported illusory movement, he was instructed to turn around and look into the main laboratory through the open rear wall of the experimental room. But even after he had thereby established the fact that only the experimental room had been moved, he again experienced the illusion that his body had moved when he faced back into the small room.

During some of the tests of Section I, the subject was given a plumb line to hold and was asked to view it in front of him while chair and room were moved and perceived in various positions. Under condition 1, when chair movement stopped with chair tilted and room upright, all of the subjects perceived the plumb line as hanging straight down. However, under conditions 2 and 3, when room movement stopped with the room tilted, there occurred a very strong and persistent illusion that the plumb line was suspended at an angle, in a direction opposite to the tilt of the room and to an extent corresponding to the angle of room tilt. This illusion occurred regardless of whether the body was tilted or upright at the time. So vivid was the illusory effect that the subject rarely considered the fact that a plumb line hanging freely from his own hand must of necessity represent the true vertical. Instead, a variety of alternative explanations was offered. Some subjects thought that an invisible wire must be pulling the plumb line to one side, others said that its position was controlled by a magnet outside the room, and others suggested that a blast of air was being

directed at it Many simply stated that this apparent violation of the laws of gravitation was beyond their comprehension

It is significant for understanding the relative importance of body cues and visual cues that the plumb line retained the same apparent position (*i e*, vertical) when its relation to the body was changed, whereas its apparent position was radically affected when its relation to the visual field was changed As long as the visual field actually remained upright, the plumb line continued to appear vertical whatever the position of the body, but, if the visual field was tilted, the plumb line appeared slanted regardless of possible cues from an erect body position The illusion evidently depends upon displacement of the visual perceptual field from the upright, and occurs regardless of what the position of the body may be

SECTION II QUANTITATIVE TESTS OF THE PERCEPTION OF FIELD AND BODY POSITION

Procedure. In these experiments the subject was required to adjust the controls of room or of chair so that, following a displacement of room or chair, according to instructions he returned either the room or the chair (*i e*, his body) to what he perceived as the true vertical [1]

The room and the chair were first brought to one of the positions listed below The subject then was instructed to operate the control at his chair so as to straighten the room (tests A, B, and C) or his chair (tests D, E, and F) to what he perceived to be the true upright The test situations were as follows

Test	Condition	Subject's task
A	Chair upright, room 35° L or R	To adjust *room* to the "upright"
B	Chair 22° L, room 35° L	To adjust *room* to the "upright"
C	Chair 22° L, room 35° R	To adjust *room* to the "upright"
D	Chair 22° L, room 35° L	To adjust *chair* to the "upright"
E	Chair 22° L, room 35° R	To adjust *chair* to the "upright"
F	Subject's eyes closed	To adjust *chair* to the "upright"
(control)	Chair 22° L, room upright	

[1] This set of procedures represents an adaptation of the psychophysical Method of Average Error, in which the subject himself operates the changing of the variable stimulus (here his apparent position or the apparent position of the room) until it is equal for him to a standard stimulus (here, the true vertical) The difference between his judgment and the standard value (*i e*, the actual vertical) thus is a measure of the illusory effect on a given trial, and the average of such "errors" expresses the magnitude of the typical illusory effect in his case

The conditions of the respective tests in section II are represented graphically in Fig 39 It will be noted that the room had to be straightened while the body was upright (test A), tilted with the room (test B), and tilted opposite to the room (test C), and that the body had to be straightened while the visual field was tilted with it (test D), tilted opposite to it (test E), and absent, in effect (test F) The trials of tests B and C were alternated, as were the trials of tests D and E

Fifty-four subjects were given the first five test conditions Twenty-three of these subjects were given test F as well

The standard procedure on each trial was as follows After the subject had closed his eyes, the experimenter brought chair and room to their required initial positions Upon opening his eyes, the subject was asked to describe his position and the position of the room Then the subject himself straightened the chair or the room, according to instructions, by turning the appropriate control In every test, while the room or the chair was being adjusted, the other (*i e*, chair or room) remained in its initial position throughout

The tests involving adjustment of the room depended upon the assumption that the degree of tilt of the room (*i e*, the angle it forms with the true vertical) when the subject perceives it as upright provides a measure of his "extent of acceptance" of the visual framework A subject who perceives the room as straight when its initial tilt is 35 degrees thus shows a larger error (*i e*, a greater acceptance of the field) than one who must move it to a point only 10 degrees tilted before he perceives it as straight Similarly, in the tests requiring adjustment of the chair, the assumption is that the farther the body is tilted toward the prevailing field when it is finally perceived as upright, the greater is the subject's dependence on the visual framework in his perception of body position

Results The average amounts (*i e*, "Average Errors") by which the adjustment of room or chair differed from the true upright under each test condition are given in Table I To show the magnitude of the individual differences in these tests, frequency distributions of the results for room adjustments are presented in Fig 40 and for the chair adjustments in Fig 41

From Table I it will be seen that under the conditions of Test A, the room was still tilted by 11 7 degrees on the average when per-
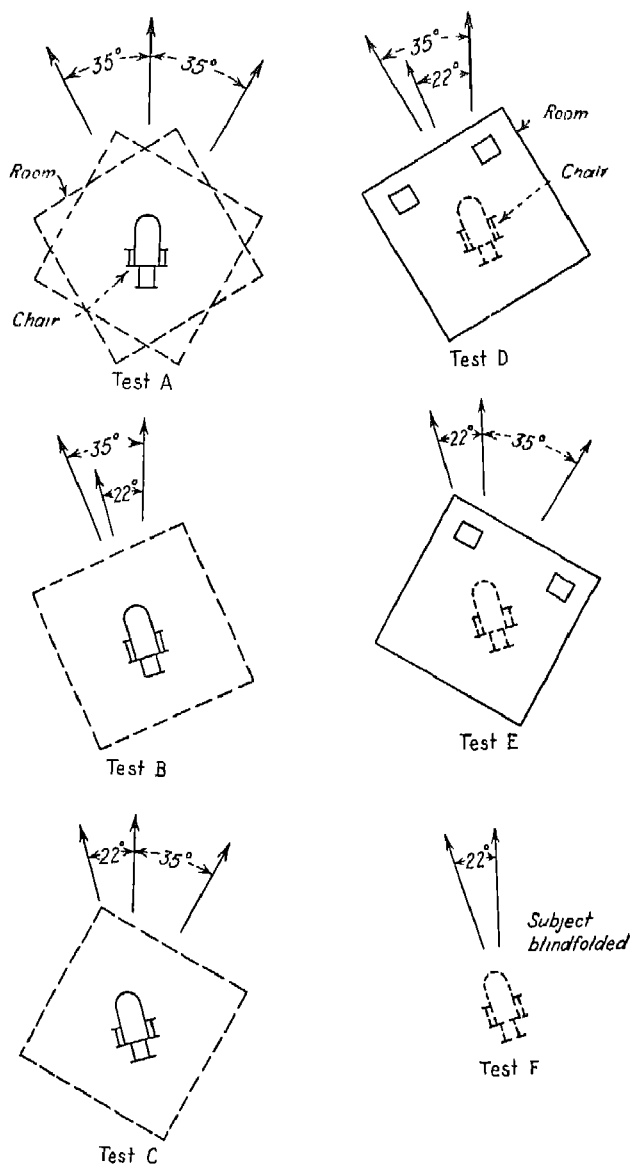
FIG 39 Schematic Representation of the Initial Positions of Room and of Chair in the Six Tests of Section II

The one (i e , room or chair) to be made "upright" by the subject in each test is indicated by dotted lines in the figure The amount by which each is initially displaced from the vertical is also indicated

ceived as upright In 90 4 per cent of the trials the room remained tilted toward the side of its initial displacement after the subject had finished his adjustment, and in only the remaining 9 6 per cent of the trials was it brought to the true upright The subjects thus tended to accept (*i e*, to be "taken in by") the visual framework in its original terms, *e g*, tilted to the right However, there were striking individual

TABLE I

Average Errors of Subjects in Adjusting Room and Chair in the Tests of Section II

Task	Test	No of subjects	Initial positions of chair and room: Chair	Initial positions of chair and room: Room	Average error (in degrees)	Percentage of trials chair remained on side of its initial tilt after subject's adjustment
To make room upright	A	50	Upright	35° R or 35° L	11 7	90 4
	B	55	22° L	35° L	12 2	76 8
	C	53	22° L	35° R	22 3	90 1
To make chair upright	D	47	22° L	35° L	9 4	97 0
	E	48	22° L	35° R	5 9	66 3
	F	23	22° L	(eyes closed)	2 4	—

differences in the extent to which the visual framework was accepted, as Fig 40 shows Although one subject was able to bring the room to within an average of 1 degree of the true upright, two other subjects on all their trials perceived the room as straight from the beginning, and therefore made the maximum error of 35 degrees[1]

Although in test A the subject sat erect and had only to readjust the room to realignment with his body, his upright position, surprisingly enough, did not lead to a more accurate adjustment of the

[1] In further experiments it has been found that some subjects perceive the experimental room as upright at tilts even greater than 35 degrees, and as great as 60 degrees in some cases

room The reason is that perception of the body itself was usually affected by the tilted framework, so that most subjects perceived the body as tilted in the opposite direction to the room Although some of the subjects recognized the illusory character of the experience, for
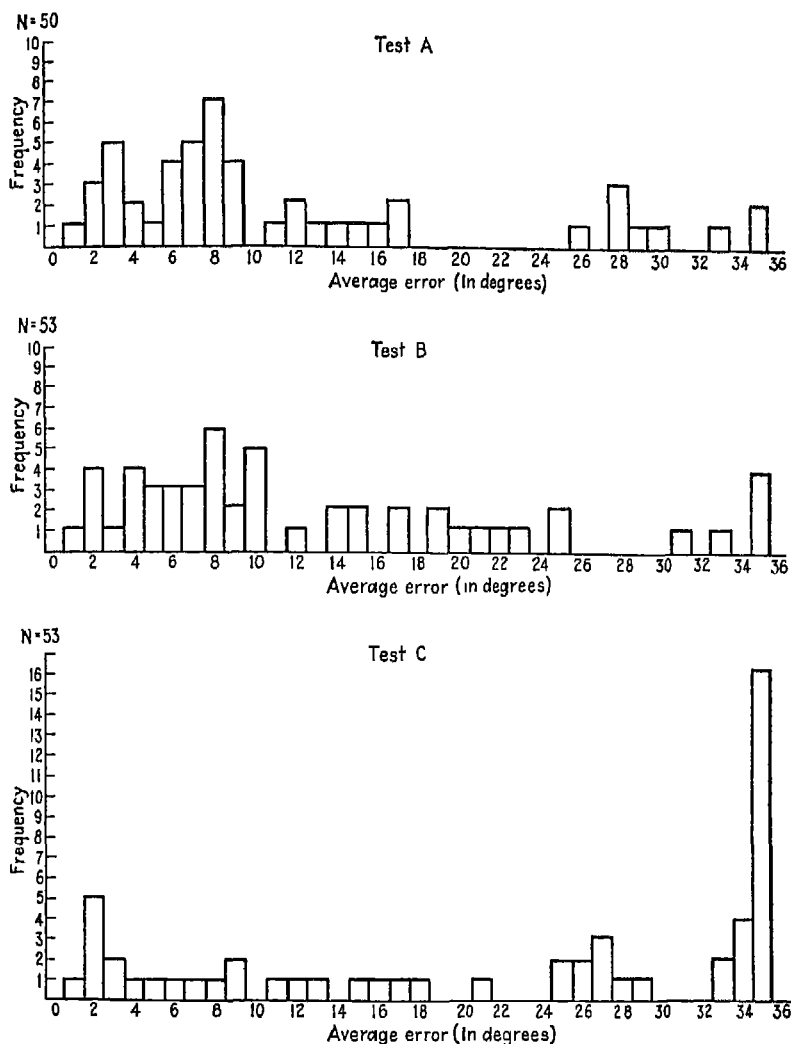
FIG 40 Distribution of Individual Scores for the Room-adjustment Tests (Tests A, B, and C) in Series II

The initial setting in each test is given in FIG 39

others the illusion was strong enough to induce false chair-pressure effects Consequently the upright body was not too useful as a source of cues for perceiving changes in room position

In tests B and C of section II, the averages of the subjects' errors were 12 2 and 22 3 degrees, respectively In these cases also the errors were most frequently in the direction of initial room tilt, as may be seen in the last column of Table I Consequently, as in test A of the series, the subjects tended to accept the tilt of the field as presented

When room and chair were tilted in opposite directions, as in test C, the average error was considerably larger than when they were tilted to the same side, as in test B Thus in test C, 16 subjects on all trials perceived the room as "upright" at its initial 35-degree tilt, but there were only four subjects who did so on test B This finding also confirms the conclusion that the perception of the vertical was more distorted, that is, the field was more readily accepted, when the room was tilted oppositely to the body than when tilted in the same direction The main reason is that, when the field is tilted in the same direction as the body, some of the subjects infer that the field cannot be upright because it is displaced farther (at 35 degrees) than is the tilted body (at 22 degrees) Such an inference is not possible when the room is tilted opposite to the body

Under the control condition in test F, with visual cues absent, the average error was only 2 4 degrees, demonstrating clearly that the body position can be established fairly accurately on the basis of postural and body cues alone But in tests D and E when the same task was given in a tilted visual field, significant errors appeared which were attributable to the position of the visual field itself Thus in test D (with chair and room tilted to the same side), an average error of 9 4 degrees was found, indicating that when the body was perceived as upright it actually was tilted 9 4 degrees

In test D, as in the earlier tests, there were marked differences among subjects in the extent to which body position was determined on a visual basis Some subjects brought their bodies close to the true upright notwithstanding the tilted field, whereas others were so influenced by the visual field that errors up to 31 degrees were made

In test E, in which chair and room were tilted oppositely, the average error for all subjects was 5 9 degrees, definitely smaller than in test D With the room now tilted to the right, only 66 3 per cent of the errors in making the body upright were in the same direction in contrast to

97 per cent in test D Clearly, the judgment of body position was more strongly influenced by the tilted field in test D than in test E It is suggested that in test E, with the subject initially tilted 22 degrees
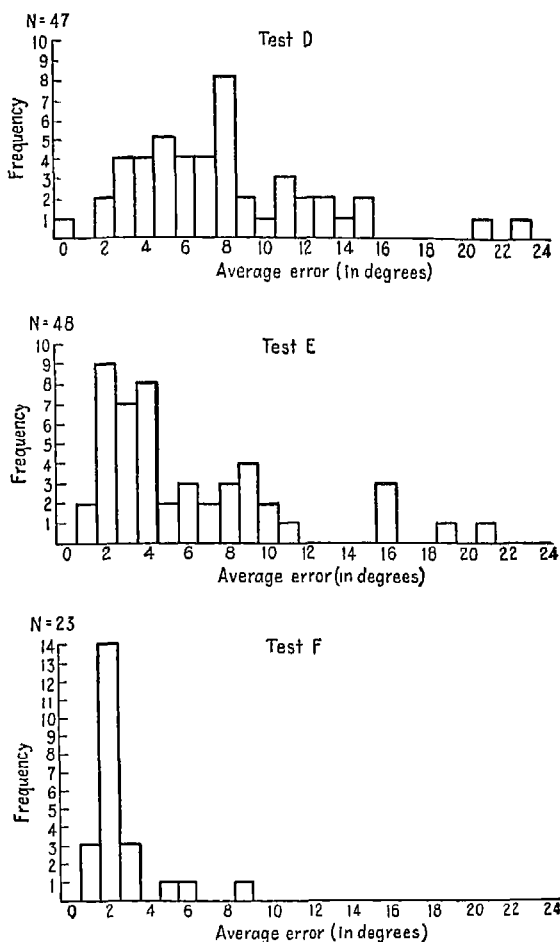
FIG 41 Distribution of Individual Scores for the Chair-adjustment Tests (Tests D, E, and F) in Series II

The initial setting in each test is given in FIG 39

left and the room 35 degrees right, he not only felt his body as tilted to the left but also *saw* it tilted to the left, so that it had to be moved toward the right to be perceived as straight However, in moving the

body toward the right there occurred a shift in weight (hence in pressure) from the left side to the right as the chair passed the upright position This shift called attention to the body and emphasized body cues, thereby reducing the effect of visual impressions and leading to judgments which fell nearer to the true upright In test D, however, no such "body-orienting" experiences occurred, and the resulting predominance of visual impressions led to larger errors

The question arises whether postural and pressure effects from tilting were really ineffective in the visually dominated subjects, or if they were influential, what their role may have been How could a subject maintain that his body was "upright" when he was actually tilted, with chair pressures very asymmetrical? The case reports show that some of the subjects under these conditions *actually experienced no pressure whatever* In other words, the experience of *appearing* straight evidently was so strong that the effects of contradictory body cues were somehow entirely inhibited and so not perceived at all With other subjects, some pressure was experienced, but, as one practiced subject said, this constituted a "remote, intellectual awareness, which seemed to have nothing to do with the strong, certain, and immediate experience of being straight " Usually in such cases specific questioning was necessary to elicit statements about pressure effects The pressures appeared to have been either disregarded or attributed to some imaginary cause Finally, there were subjects who experienced pressure effects when they erroneously judged themselves to be upright, and who did not simply discount them or rationalize them away Such subjects, after repeated attempts to find a normal position, would report that for unknown reasons they could not *feel* erect and *look* erect at the same time For them, a choice of position generally was reached only after much shifting back and forth, and represented a compromise which was frequently very unsatisfactory to the subject

In this section of the investigation there was no actual measure of the extent to which pressure or body cues were experienced To investigate this matter, tests A to F were repeated under two conditions, in both of which the experimenter moved the chair in 2-degree steps until the subject reported himself in an upright position The difference between the conditions was that for the *experimental* group of this series the *elimination of pressure inequalities* through chair ad-

justments was emphasized in the instructions as the task to be accomplished, whereas the *control* group was required only to report when an (apparently) upright position had been reached, with no mention of equalizing pressure effects

Notwithstanding the difference in instructions about pressure, the results for the two groups were much the same In both groups, the body was usually still tilted when perceived as upright, and by similar amounts, *i e*, the average errors were similar For example, under the conditions of test D the Average Error was 13 3 degrees for the control group and 15 9 degrees for the experimental group, under the conditions of test E the Average Error was 7 8 degrees for control and 10 4 degrees for experimental subjects Thus the results were much the same whether or not the instructions emphasized pressure effects

The results of tests D, E, and F indicate that the perception of body position depends not only on how the body feels, but to an even greater degree on how it looks to the subject in relation to his surroundings If the subject is to perceive his body as upright, when he is in a tilted field, he must be moved toward alignment with the field These tests also disclose that some people seem to rely primarily on the visual relationship between the body and its surroundings, presumably either suppressing contradictory body effects or perceiving them as remote from their experiences In contrast, other subjects are less affected by visual impressions and seem able to make good use of body cues in judging their position The ranges found in the amount of error (from 0 to 31 degrees in test D, and from 1 to 24 degrees in test E) reflect the magnitude of such individual differences The cause of some of these variations will be investigated in the next section of this chapter

SECTION III QUALITATIVE DIFFERENCES IN PERFORMANCE

An examination of some of the case reports, especially those of subjects whose orientation was very poor, will offer a basis for understanding the nature of the different adjustments to these situations The following excerpts are taken from the protocols (case records) of a set of experiments already referred to in which the experimenter made the adjustment for the subject by moving room and chair in small steps until the subject reported them to be straight

Protocol for Subject A. Under conditions equivalent to those in test B of Section II (with the difference in procedure noted above),

this subject, in accepting the experimenter's adjustment of the room to the upright from 35 degrees right or left on successive trials, made error scores of 18, 31, 32, 32, 7, and 35 degrees, indicating a marked acceptance of the visual field Although on the first trial (under condition B) she was able to accept an adjustment within 9 degrees of the true upright, on the next two trials she was in error by 32 and 24 degrees, respectively In test C, when the room was initially at 35 degrees right and the body at 22 degrees left, she accepted the room as straight at once on the first trial, and on the next two trials she was off by 37 degrees each time

On the second trial of tests D and E, where the chair was initially tilted 22 degrees left and the room 35 degrees right, very severe disorientation developed, as the following excerpts from the protocols show very clearly

First the subject had herself moved past the upright in the direction of room tilt, until she was tilted 24° right Then she said "No, I'm at an angle There are difficult things to decide I feel by my weight that I'm thrown to the right Move me to the left No, to the right No, maybe more to the right No, I wish I could tell you, move me more to the right That's it"—Her difficulty was that when her body looked straight to her in relation to the room, she felt tilted, and when she felt straight she looked very tilted

At 26° right, later "I feel cockeyed Go to the left I'm sorry if I sound dumb, but I can't get myself straightened out"—At 24° right "I'm beginning to be on my head (Excitedly) Turn me to the right I've never been on my head before I'm almost on my head now No wonder I couldn't tell" At 40° right "I'm approaching being on my head Let's experiment some more Move me to the left"—At 26° right 'If you want to, you can say I'm on my head now I can't say definitely, but let's say I'm fairly sure I'm on my head I feel very stupid Move me to the left"

—Considerably later, at 18° right "I'm going back on my head Ah, I know The walls are moving too" When asked whether it was possible to get straight, she replied "Not by moving left and right Move the walls back (pointing to the front wall of the experimental room), we're both oriented down The front wall is becoming the floor If you tipped it over a little (pointing upward) it would become the floor" When asked where the floor was, she replied "It's where you are" (Here she judged the open back wall of the room to be the floor, —a plane at right angles to the true floor of the experimental room!)

The trial was discontinued soon after this, since it was clear that this subject would not be able to regain her bearings sufficiently even to approach making herself straight When returned to the actual upright, she exclaimed "Oh, it's wonderful! I was hanging like a crescent moon"

This performance has many interesting features. First with rather slight tilts of the chair and room, and these in the right-left direction only, the subject experienced extreme changes in her own perceived position and in that of the field. Concerning her own body she experienced the illusion of tilts in the front-back direction, as well as spiraling movements, and during a considerable part of the last trial she felt herself to be on her head. With respect to the room, at one point she perceived its *front wall* as the ceiling, and at another point as the floor. These shifts in the perceived orientation of the room occurred while the room remained in the same position and came about quite suddenly. Thus on one occasion, after reporting that the front of the room was becoming the floor, she exclaimed, "Now I have a completely different orientation. We're climbing, and the front wall is nearer to the ceiling." Of importance also is the severe disorientation suffered by this subject. At many points her perceived upright was far from the true spatial upright. At times she became extremely confused about where the upright was, so that on the last trial she failed to find a position where her body seemed upright, after trying for 50 minutes. Such experiences proved very disturbing to the subject throughout most of the test.

The difficulties experienced by this subject undoubtedly resulted from a strong tendency to perceive the upright primarily on the basis of visual impressions, and an insufficient reference to the body. Thus she accepted the tilted room as straight, even when she sat erect and had maximal use of body cues.

Protocols for Subjects B and C. Another example of disoriented performance in these tests, associated with poor scores, was provided by subject B. On the three trials of test A in which the room was tilted 35 degrees left with the chair upright, she perceived the room as straight at the very outset, and accordingly reported that her erect body was tilted far to the *right*.

On trial 2, with chair 22° right, room 35° right, she said "Ah, me, the floor is the left wall and the ceiling is the right wall. (When asked if the room was straight—) I can't decide. (After a long pause—) I'm trying to figure it out. I'm tilted to the *right*, and if I were straight how would it look? It's down to the left."

On trial 5, with chair 22° left, room 35° right "The room is straight. It's

again in order The chair is slightly to the *right* Then why don't I fall to the right? There is something very mysterious You must have magnets"

The difficulties of subject B, as with A, depended upon the fact that her perception of the visual field was dominant Her confusion became so great that even after detecting the tilt of the room she could not tell which way it had to be moved to become straight Closing her eyes to eliminate the confusing influence of the field did not help her, for as soon as she looked again at the room she came so strongly under its influence that the impression of body position established with eyes closed was obliterated Not only did she have gross misconceptions about the position of her body and of the field, but she experienced difficulty in making her judgments She was hesitant and unsure throughout, each decision required a great deal of time and then was often made quite without confidence Like subject A, she was markedly disturbed, often emotionally agitated

Subjects A and B were both very intelligent, but neither was successful in overcoming her strong visual impressions through an intellectual treatment of the situation Another very intelligent subject, C, had the technical knowledge concerning sensory mechanisms necessary to deal with such conflicting experiences Yet despite his knowledge, and his effort to "figure out" each situation, he gave a highly confused performance similar to that of subjects A and B, as the following excerpt from his protocol shows

On one trial, with the chair initially 22° left and the room 35° right, his comment was, "I'm on the left side and the room is a little to the right" (When the chair had been moved toward the right to a point where it was 14° right, he said) "Wow! I'm upside down I feel suspended from the floor position I have a hunch, though, that objectively I'm still a little to the left, yet when I look it seems the right wall is the bottom, even though I know it is not so I'm jutting out like a branch from the floor part, that is now the left wall, but I know it's not true —I could find out by spitting"

Thus the subjects who were very strongly influenced by visual impressions in this situation were not assisted much by their intelligence, or even by technical knowledge, to counteract these impressions and achieve a satisfactory integration of visual and postural experiences

Comments such as the above occurred almost exclusively among subjects who made very large errors in judging the upright Confusion among other poorly performing subjects usually was milder, more

transitory, and limited to a part of the test As a rule, the judgments of subjects with large errors were made rapidly and without evidence of conflict, with a rather "glib, unquestioning acceptance of the visual field" As difficulties arose, this type of subject as a rule soon gave up trying, often with the assertion that she had done her best

SECTION IV SYMPTOMS OF EXTREME DISORIENTATION IN AN UNSTABLE VISUAL AND POSTURAL SITUATION

In the course of the above experiments, some of the subjects complained of "illness" and reported symptoms which usually included (in order of prominence) dizziness, sweating, headache, and nausea To investigate this reaction to the experimental conditions, tests consisting of special combinations of room-and-chair movement (as in Section I) were given, each of them presented ten times to each subject The following combinations were used

1 The subject was tilted through an arc from 10 degrees left to 10 degrees right of the vertical, first with eyes closed, next with eyes open

2 While the subject remained upright in the chair, the room was tilted from 10 degrees left to 10 degrees right, then from 35 degrees left to 35 degrees right

3 The subject and room were moved together, from 15 degrees left to 15 degrees right, then oppositely—for example, chair to 15 degrees left, room to 15 degrees right

The results consistently showed that body movement, whether with eyes open or closed, produced no ill effects whatever When body movement was combined with room movement, some "illness" appeared, but it was only occasional and usually was mild However, severe discomfort and "illness" appeared with room movement alone, and particularly with the 35-degree room displacement

In connection with tests A to E of section II, discomfort and "illness" were frequently reported when a subject opened his eyes at the beginning of a trial and found the room and chair in very different positions The speed with which the illness developed and the circumstances of its occurrence strongly suggest that it was a consequence of being confronted suddenly with a very unstable situation In agreement with this interpretation, the results show that motion of the visual field when the room was tilted set up an illusory body movement

which was inconsistent with actual body pressures, and therefore very confusing and disturbing In the tests involving a back-and-forth tilting of the room with the body stationary, some of the subjects experienced severe discomfort at the moment when the room movement was reversed in direction It was also at that moment that the subject had their greatest difficulty in perceiving what was happening

The reason for such difficulties seems to be that a change in body movement draws attention to the body, thereby reinstating a conflict between visual and postural cues—a conflict which is stilled by the dominance of visual impressions during continuous movement When there is marked disorientation and uncertainty as to whether the room, the body, or both room and body are moving, and the disparity between visual and postural sensory effects is at its height, the organic symptoms of "illness" characteristically appear Thus when the room was tilted, although it was stationary at the time, some of the subjects complained of lost bearings and a "topsy-turvy impression," accompanied by dizziness and nausea When orientation is relatively secure and there is no sensory conflict, "illness" does not develop

A somewhat comparable situation, very disturbing to some people, is the experience of being momentarily disoriented when sitting in a moving train that is passed by another train An experience of dizziness and nausea is not uncommon under such conditions Such effects are accentuated when a sudden shift occurs in the field of moving objects, as when a train on a nearby parallel track begins moving in a direction opposite to that in which one's own train has been moving In these circumstances, it is even possible to refer the experienced nausea and organic discomfort to an attitude of emotional apprehension (*i e* , anxiety) which is a typical reaction to very unstable situations In fact, some of the subjects in these experiments, who asked that the movement of chair and room be stopped immediately after it had begun, described their distress as "anxiety" or "anxiousness," and seemed to perceive the situation as a threatening one This type of "illness" is somewhat different from the "motion sickness" (*e g* , seasickness) sometimes experienced in body-movement situations, which is more dominantly physiological in nature and commonly involves actual vomiting as a symptom

A situation comparable to that described above is involved in a

common form of "airsickness" likely to be met with by inexperienced pilots undertaking somewhat abrupt and difficult maneuvers. Under such conditions, when the plane banks suddenly, the pilot is likely to perceive the earth's surface precipitately turned on its side, as it were and sharply inconsistent with his body position at the moment. Then a condition of acute disorientation and anxiety may seize him, which often immediately involves symptoms of illness such as those we have described.[1] The individual's distress may be increased by an added organic upset attributable to a direct stimulation of the viscera and of static receptors by the radical bodily displacement itself.

DISCUSSION

The experiments of Witkin show that perception of the position of the body at any given moment typically depends more upon visual impressions than upon postural cues. The results show that to understand the specific way in which visual impressions help to determine our perception of our body's position, it is necessary to consider not just the body itself, but also the body in relation to its surroundings. When the subject's body was aligned with the vertical axis of the visual field he reported that his body looked straight to him, and when it was displaced from this axis his body tended to look tilted. The subject's judgment of his own position often seemed to be a very strange one, until the specific manner in which he saw the field surrounding his body became known.

These findings support the generalization that the perception of an object is influenced greatly by the surrounding field (*i.e.*, the field of which the object is a part), and because objects rarely occur for us in isolation, the results apply to the perception of most objects in the environment. In fact, the surrounding field may be expected to exert an even greater influence on the perception of external objects than on the perception of the body, for the body provides sensory cues useful in judging its position—cues which arise independently of the field. Other experiments, in which subjects determined whether an external object was upright or tilted, provide further examples of the way in which the surrounding field influences the perception of objects within it. Thus, most subjects standing erect in a dark room tended to view a

[1] Armstrong, H. G. *Principles and Practice of Aviation Medicine*. Baltimore, Williams & Wilkins, 1939.

luminous straight rod (placed vertically in all trials) as tilted or as upright depending upon whether a luminous square frame surrounding this rod was tilted or upright.[1] Also, as would be expected from the foregoing discussion, whatever tilt was perceived in the rod seemed to be in the direction opposite to the tilt of the field.

Other cases of perception provide further examples of the principle that the perception of objects depends upon their specific relation to the field in which they are viewed. Thus a medium-gray object will appear brighter in a field of dark gray than in a field which is light gray. It is mainly the brightness of an object in relation to brightness of surrounding surfaces, rather than the absolute brightness of that object, which is important. As another example, the apparent distance of an object from us depends not merely upon stimuli from the object itself but to a large extent on the relation of the object to other objects in the surrounding field. Thus, a distant house which is partially blocked from our view by another usually is perceived as farther off than one actually at the same distance but in unobstructed view. If an object, especially one that is familiar, seems smaller than other objects of the same class and size (*e.g.*, a row of oak trees on a hill), or is less clear than other objects, it is likely to seem more distant. If, while one moves his head, an object remains stationary while other objects seem to move across the field in relation to it, the still object will be perceived as more distant. Innumerable examples may be found to demonstrate that the perception of an object and its qualities depends not simply on the object itself but also on its context—that is, on its background and its relations to its surroundings.

An important question attacked in the present studies was the basis of the constancy of the perceived vertical and horizontal in everyday experience. Notwithstanding many variations in our specific postural orientation, we normally continue to perceive the vertical and horizontal accurately. The results of the described experiments suggest that this perceptual constancy depends primarily on the highly stable visual field about us. For example, when the room was tilted, subjects tended to accept its upright as the true upright. They were likely to underestimate the tilt of the field more or less—for example, in straight-

[1] Witkin, H. A., and S. E. Asch. Studies in Space Orientation. IV. Further Experiments on Perception of the Upright with Displaced Visual Fields. *Journal of Experimental Psychology*, 1948, vol. 38, pp. 762–782.

ening the body they tended to displace it toward the perceived vertical of the field, as in readjusting a picture on the wall of a room, one tends to move it into line with the room's main axes

Any characteristics which tend to emphasize the visual field (e g, pictures on the wall in front of the subject's chair) also tend to accentuate the extent to which the perceived vertical and horizontal shift with the field as the latter is moved The perceived vertical and horizontal seem to be "anchored" to the visual field, and with a field as "strong" as that provided by our everyday surroundings, these perceptions are almost certain to depend upon its dictates Not only is the normally prevalent visual field a strong one in this sense, but it is also highly stable in that it represents the vertical and horizontal correctly, i e, in accordance with gravity In view of these facts, the constancy with which we perceive the spatial planes is not surprising

The important role of the visual field in the adequate perception of the upright is shown by the very limited effect of changes in head or body position when a visual field is effective In the present experiments, changes in body position in the presence of an upright visual field were without effect in producing perceptual errors, whereas changes in the field (even with the body upright, as in test A, Section II) led to marked illusions

It is clear that *constancy in our adult perception of the upright must depend for its development on the presence of a stable visual field of the kind normally provided by our surroundings, and on the effect of a gravitational force which is consistently related to the principal visual axes as encountered in everyday life* That is to say, *a consistent set of relationships between body position and environmental circumstances influences the basic development of our processes in space perception*

Ordinarily it is not possible to determine whether the perceived upright is based more upon postural factors or upon visual This is because the gravitational factor and the verticals of the visual field coincide in direction, so that the result is the same whether judgments are based upon one or the other However, these experiments, by providing unusual situations involving variable displacements of the visual field and of body position, afforded a means of separating the roles of visual and postural factors From the results, it is clear first of all that when the visually and posturally indicated uprights are in conflict, the subject's perception of "upright" generally is not based

simply on the one or the other but represents a compromise between the two The findings show that this compromise depends mainly on the "strength" (*i e*, detail, extent of accentuation) of the visual field Similarly, a visual field of the kind predominant in everyday life dictates the accepted "upright" in perceptual situations more effectively for most people than do postural factors

However, it is imperative to recognize that people differ from one another with respect to the relative importance of these factors In a given situation, although most people favor the visual field as a basis, others rely more on postural cues derived from the body itself The point may be emphasized by inspection of the individual differences represented in Figs 40 and 41.

Furthermore, in perceiving the upright some individuals tend to be more consistent than do others in their degree of dependence on the visual field as it appears in different situations However, it may be said that on the whole the characteristics of a particular individual in perceiving the upright in one kind of situation also appear definitely in other and different situations For example, supplementary to the tests of Section II, one group of subjects was given a test in which a previously viewed simple figure was to be identified in a larger complex figure designed to "hide" or "embed" the simple figure Success in this type of perceptual task requires that the subject not "go along with" the total visual field provided by the complex figure, but deal with its constituent parts in a somewhat flexible and independent manner It is not surprising that a fairly high correlation ($r = +.61$ for men, $r = +.51$ for women) was found between the results for the same subjects in the "hidden figures" test and those for tests involving adjustment of chair and room to the vertical, for analysis reveals that a similar process is involved in the two situations Thus, subjects who have difficulty separating their bodies perceptually from the surrounding field also find it difficult to discern the simple figure when it is "embedded" in complex surroundings Individual characteristics in perception thus appear to be somewhat generalized, so that they are revealed in recognizably similar ways even in situations where the specific perceptual tasks are quite different

It is clear that a knowledge of the field conditions (*i e*, the stimulus objects) alone, important as these conditions are, cannot provide an adequate understanding of how a given person will perceive a particular

situation If field conditions were the sole determinants of perception, then, notwithstanding individual differences in sensory and neural equipment, people would be expected to perceive much more similarly than they do The fact that marked individual differences in perception appear under equivalent external conditions, and furthermore that most individuals tend to show fairly stable and consistent perceptual characteristics, emphasizes the presence of further internal determinants of perception which are unique to the individual and which influence his perceptual organization of a particular situation Further experiments now in progress suggest that at least some of these highly individualized determinants of perception are related to and dependent upon the motivational characteristics of the person

CHAPTER XXII

PERCEPTION AND MEMORY AS INFLUENCED BY ATTITUDE AND EXPERIENCE

Introduction

A camera is a mechanism by means of which patterns of light chemically transform a sensitive film and leave lasting traces upon it In much the same manner, living organisms are affected by the stimuli which impinge upon them, and the effects of these stimuli persist often over long periods of time This persistence of the effects of stimulation is what is meant by retention, or memory

Although the impression left on a photographic film bears a close resemblance to the object which was photographed, it is not a precise copy of that object A photograph of a tree is smaller than the tree, it commonly lacks the tree's colors, and, unless the camera lens is exceptionally good, the edges of the picture are blurred What is impressed upon the sensitive film, therefore, is determined not only by the character of the object producing the impression, but also by the structural characteristics of the recording mechanism itself (primarily of the lens and the film) The differences between the object photographed and the resulting photograph depend upon the deficiencies of the camera mechanism

In some respects, the functioning of the human memory mechanism resembles that of the camera As a rule, what we remember has a definite similarity to the pattern of stimuli which furnished the basis for the memory But we do not remember perfectly Memories are generally incomplete and defective in the sense that they do not reproduce in a literal way the past objects or events which they represent If you were asked to recall the first paragraphs of this chapter, you might be able to state their general import, perhaps reproduce some of the exact phrases, but it is very doubtful that you could achieve a letter-perfect copy The fallibility of our memory processes is brought home to all of us many times each day We are frequently confident

that we are recalling an object perfectly, yet our recollection generally proves very defective when compared with the actual object

Certain of the factors which make the memory of an object deviate from that object are similar to the factors which limit the accuracy of a camera With respect to visually perceived objects, for example, faulty eye structure, like faulty camera construction, causes distortion of what is seen, and consequently of what is remembered [1] However, the analogy between photography, on the one hand, and human perception and memory, on the other, is a very incomplete one Whereas the aberrations in a camera record result from faults in the mechanisms of lens and sensitive plate, the discrepancies between the visual perception and memory of an object, and the object itself, are chiefly attributable to factors other than the eye alone

The human organism is an inconceivably more complex instrument for the reception and recording of impressions than is any camera In photography, the character of a particular picture on a roll of film is not affected by the nature of the pictures taken previously But in human perception and memory, what one perceives at a given time may be greatly influenced by what one has perceived at an earlier period A very simple illustration of this fact is furnished by the phenomenon of "successive contrast" (*e g* , the unusual brilliance which bright objects appear to possess when they are viewed after dark ones) But the fact that our perceptions and memories are influenced by antecedent events is true in a very wide and complex sense, as well We see particular groupings of black marks on white paper as letters and words, only because our training has provided the foundation for that observation The patterns of light and shade that we see, the sounds that we hear—in fact, everything that enters the channels of sense—are perceived and remembered in terms of experiences prior to the perception

A second point of difference between the functioning of the camera and of the human organism is the fact that, unlike the photographic record, the perception and memory of an object are affected by the nature of the situation in which the object appears The photo-

[1] Here belong such defects as disproportions in the shape of the crystalline lens or in the length of the eyeball (which produce nearsightedness or farsightedness), imperfections in the curvature of the cornea, lens, or eyeball (which result in astigmatism), inadequate ocular coordination (which causes the seeing of single objects as double), and peculiarities in retinal structure (*e g* , those which underlie color blindness)

graphic image of a given tree would be exactly the same, regardless of whether the tree were flanked by other larger trees or stood alone on a grassy bank But our impression of the size and shape of an object may be influenced by almost any irrelevant stimuli which are simultaneously present Thus, a tree of a given height would be perceived and remembered as shorter if it stood beside a number of taller trees than if it were surrounded only by low shrubbery Similarly, if two black circles of equal size are drawn, one in a small and the other in a large white square, it is the circle in the smaller square that is perceived and remembered as definitely the larger

The influence of stimulus setting and background upon perception is especially apparent in illusions such as the Muller-Lyer illusion and the size-weight illusion In our everyday experience, illusions due to this factor of context occur quite frequently However, it is only when a particularly obvious error is made (*e g*, when one boisterously greets a stranger whom one has mistaken for a friend) that such false perceptions are identified as erroneous or illusory Because of this fact, we ordinarily do not realize that our perception of a given object may vary greatly from one occasion to another, as a result of differences in the settings in which the object appears Although we may think that we are attending exclusively to certain items in a complex of stimuli, our perception of these items is influenced by other factors in the situation

Finally, the memory of an experience may be affected by subsequent experiences In photography, the seventh picture on a roll of film is not changed by the later exposure of picture number eight But a particular painting in a museum may be remembered as exceptionally beautiful, or as merely mediocre, depending on the reactions which were evoked by the pictures seen after it Similarly, one's ability to recall something he has learned may differ greatly in accordance with whether he has spent the time between the learning and the recall test in sleeping or in pursuing ordinary daytime activities [1]

Evidently, therefore, both the perception and the memory of a given experience are influenced by previous and by contemporaneous experiences, and the memory of an experience is likewise affected by events which follow it

[1] For a report of experimental studies on this subject see Chap XVI

The various ways in which a person's past experience may affect his perception and memory of things and events have been the object of many recent psychological studies In all these investigations, each stimulus presented is the same for all the subjects, the experimental variable is the background of experience of the subjects themselves If these identical stimuli are perceived and remembered in different ways by different subjects, such variations must be the result of differences in the subjects' past experiences

In certain investigations of this problem, the experimenter himself produces the differences in the experiences of his subjects by varying the instructions or suggestions that he gives to them The experimental "creation" of such differences is analogous to many familiar occurrences in everyday life For example, a number of people may happen to see a man lying prostrate and apparently unconscious on a city sidewalk, and later observe an ambulance arrive and take him away If one of the group chances to hear someone say, "He's drunk," whereas another happens to overhear the remark, "He's had a heart attack," and if each person accepts the characterization he hears as correct, it is virtually certain that the two persons will differ considerably in both their perceptions and their memories of the incident Such remarks constitute verbal experiences, and differences in them tend to produce corresponding differences in our perceptions and memories of the objects and events to which they refer An excellent example of an investigation in which the experimenter presented different verbal experiences to different subjects, with the aim of ascertaining the effect of these differences upon the subjects' perceptions and memories, is the study of Carmichael, Hogan, and Walter[1] which forms the principal basis of the present chapter

In another type of investigation, the experimenter does not "create" differences in the past experiences of his subjects but rather selects subjects who already differ in ways which he conceives may affect their perceptions and memories, for example, in their attitudes[2] toward various aspects of their environment To these subjects he presents

[1] Carmichael, L, H P Hogan, and A A Walter An Experimental Study of the Effect of Language on the Reproduction of Visually Perceived Form *Journal of Experimental Psychology*, 1932, vol 15, pp 73–86

[2] An attitude may be defined as a state of readiness to react in a characteristic way to specific objects or situations on the basis of factors related to the experience and the motivation of the individual

selected stimuli and observes such differences as may occur in their perceptions and memories of them Individual differences in perception and memory arising from this source are a matter of common observation Suppose, for example, that a group of people strolling on a country road includes a painter, a botanist, and an architect The color masses of flowers and foliage, the contours of hills, the interplay of light and shadow, are likely to constitute the high spots of the day for the artist As for the botanist, it may be the discovery by the roadside of an obscure lichen, not even seen by others of the group, which makes this day a memorable one for him And the architect may remember vividly only one thing about the excursion an old cottage skillfully modernized Studies of differences in perception and memory deriving from differences in vocation, race, economic status, attitude on social issues, and other factors stemming from the personal history of the subjects belong to this class of investigation Several experiments of this type are briefly reported in Part II of this chapter

The experiment by Carmichael, Hogan, and Walter was designed to investigate the effect exerted by certain previous experiences of the subject upon his perception and memory of visual designs These previous experiences consisted of various familiar words which were presented to the subject by the experimenter We are justified in speaking of the presentation of words as the giving of "experiences" to the subject Each individual has learned in the past to connect particular words with corresponding experiences, with the result that, when a specific verbal expression is presented, it serves as an effective stimulus for the recall of certain related experiences In this sense, the expression functions as a symbol for previous experience, and this experience constitutes the meaning of the expression

It is obvious that our memory of a given event may be greatly influenced by subsequent verbal experiences, *e g*, when we converse with others about some previous event, or when we think (in words) about it Similarly, it is clear that the preconceptions and expectations which color our impressions of the world about us become established largely through verbal means, *e g*, the advices and suggestions which we receive from reading or from communication with others What is not so apparent, however, is that our perception of simple, concrete objects and our immediate recollection of them may be profoundly affected by the words which we have associated with

the objects It is this phase of the effect of language experiences upon perception and memory which was investigated in the experiment reviewed below

WORD LIST I	STIMULUS FIGURES	WORD LIST II
Curtains in a window		Diamond in a rectangle
Bottle		Stirrup
Crescent moon		Letter "C"
Bee hive		Hat
Eye glasses		Dumb bells
Seven		Four
Ship's wheel		Sun
Hour glass		Table
Kidney bean		Canoe
Pine tree		Trowel
Gun		Broom
Two		Eight

FIG 42 The Stimulus Figures and Word Lists I and II Which Were Presented Together with the Stimulus Figures

I THE EXPERIMENT OF CARMICHAEL, HOGAN, AND WALTER[1]

PURPOSE

The present experiment was designed to investigate the influence of verbal symbols upon the recall of visual patterns Specifically, the aim was to discover whether the suggestion of an object-name for a visually perceived geometrical figure may affect the subsequent reproduction of that figure

METHOD

Subjects. The subjects were 60 women and 35 men All were college students or college instructors

[1] Adapted from Carmichael, Hogan, and Walter, *op cit*

The Stimulus Figures and the Word Lists. The stimulus figures were a series of drawings representing 12 simple geometrical forms. Although none of these figures was a complete or accurate representation of any object, each of them was so constructed that it resembled at least two actual objects. For each figure two names were devised, each of which was the name of an object which that figure more or less resembled. Figure 42 depicts the series of stimulus figures and gives the two lists of words, Word Lists I and II, which were assigned to them.
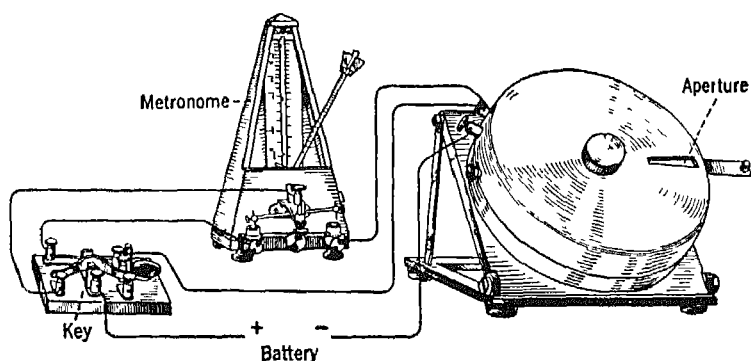
Fig. 43. Apparatus for the Presentation of Material in a Serial Arrangement

In using the instrument illustrated (the Ranschburg memory apparatus), the experimenter marks off a circular card in radii and writes in successive or alternate sectors the stimuli (*i.e.*, syllables, words, or figures) which are to be serially presented. The card is then placed upon a revolving platform under the circular cover of the apparatus. This cover is stationary and contains an aperture through which a single sector of the card can be seen. The card rotates with the platform, and the stimuli inscribed upon the card are thus brought one at a time under the aperture. By means of a metronome or some similar regulating device, the rotation of the platform (which carries the card) is electrically controlled, so that it remains stationary for a predetermined period when each stimulus item appears in the slit. Each exposure is a "still," and the shift from one exposure to the next occurs by a rapid jerk.

Apparatus. The apparatus for presenting the stimulus figures was essentially the Ranschburg memory apparatus, illustrated in Fig. 43, although certain modifications were introduced. A white cardboard disk, 19 cm. in diameter, was divided by radial lines into 30 equal sectors. The disk contained the series of 12 stimulus figures, each figure separated from adjacent ones by blank sectors. A space of seven empty sectors followed the twelfth figure of the series. The mode of operation of the Ranschburg apparatus is described in connection with Fig. 43. The stimulus figures were shown in a regular series,

probably at a rate of 2 sec for the exposure of each figure and 2 sec for each blank sector between adjacent figures

Procedure. Experimenter and subject sat opposite each other at a laboratory table The exposure apparatus was placed before the subject and the illumination was arranged so that each successive figure was clearly visible to him as it appeared in its turn in the exposure slit

Before beginning the experiment proper, the subject was told that he would be shown a series of figures, and that after the completion of the series he was to try to draw them as accurately as possible He was further instructed that he might make his drawings in any order he wished, that is, it was not necessary for the sequence of his reproductions to correspond to the serial order of the presented figures

The subjects were divided into three groups All three groups were shown the same series of 12 figures For the 48 subjects of Group A, and for the 38 subjects of Group B, the figures were designated by the object-names of one or the other of the word lists Thus, for these subjects, each time that an empty sector appeared in the exposure slit, the experimenter said, "The next figure resembles ," giving one of the two names of the figure about to appear For the subjects of Group A the experimenter pronounced the word of List I which was appropriate to the figure in question For the subjects of Group B the word was the corresponding one from List II For the nine subjects of Group C the experimenter simply exposed the series of stimulus figures without giving any names in connection with them The tests with Group C represented a control experiment

When the presentation of the series of figures had been completed, the subject was requested to draw all the figures which he had just been shown If he failed to produce a recognizable representation of all 12 figures, the series was shown again in the exposure apparatus, and for Groups A and B the experimenter used the same words to suggest the resemblance of each figure to the concrete object named during the original presentation Following this second exposure, the subject again attempted to reproduce the figures This procedure was continued until a recognizable reproduction of all 12 forms was secured [1]

The Scoring of the Drawings. After the completion of the experimental work, the papers containing the subjects' reproductions were

[1] For the achievement of this criterion, the subjects of Groups A and B required an average of three trials, the subjects of Group C, four trials

studied independently by two of the three authors serving as judges. The judges ranked each drawing on a five-point rating scale according to the degree of resemblance between the drawing and the figure which it was intended to reproduce. The rating scale was as follows:

Grade 1. Drawings that were approximately perfect reproductions of the stimulus figures.

Grade 2. Drawings "with very slight changes from the original." These changes usually took the form of "slight shortenings or lengthenings of lines, slight changes in curves or angles, or slight changes in the proportion of one part of the figure in relation to some other part of the figure."

Grade 3. Drawings which showed "a noticeable change in the original figure, but which did not mark a complete distortion." Such figures were characterized by definite increases or decreases in the length of lines, or by pronounced alterations in curves, angles, or proportions. "These figures were in all cases, however, still quite satisfactory reproductions of the original."

Grade 4. Drawings "showing marked changes such as additions or omissions, and marked changes in proportion. The figures in this group, while still somewhat resembling the original, were changed considerably from it."

Grade 5. Drawings "which were almost completely changed from the original. Here were included inverted figures, and those hardly recognizable in relation to the stimulus-figure."[1]

In the rating procedure, the judges considered each reproduction without reference to the particular word which had been associated with the figure at the time of the original presentation. After all of the reproductions had been independently rated by the two judges, their estimates of the rating-scale position appropriate to each drawing were compared. When it was found that the ratings of the two judges differed, the reasons for the difference were discussed and an attempt was made to arrive at an agreement. If, as occasionally happened, a conclusion could not be reached in this way, the third experimenter was consulted and his verdict was accepted as final.

In the opinion of the authors, the influence of any factor which

[1] The authors recognize that inadequacies must be present in a rating-scale method of measurement when the steps of the scale represent qualitative rather than quantitative units. Because of the nature of the data obtained in the present experiment, however, the authors considered the rating plan which they adopted to be the most reliable scoring device available under the conditions.

tended to produce discrepancies between the objective appearance of a stimulus figure and the reproduction of it would be most clearly revealed in the most discrepant drawings A close study of the drawings which were judged as Grade 5, therefore, was considered the best means of discovering the effects of the experimental factor being investigated, *i e*, the names of objects which the stimulus figures were said to resemble Such an analysis might have two different outcomes One possibility was that the Grade 5 drawings might show no consistent resemblance to the typical visual form of the objects which the experimenter had named In this event, one would have to conclude that, under the conditions of the experiment, the accompanying verbal stimulus was not the factor responsible for the errors in the reproductions of the visual patterns On the other hand, a greater resemblance might consistently be found between the reproductions of Grade 5 and the objects named than existed between the stimulus figures themselves and those objects Such a finding would enforce the conclusion that language may bring about modifications in the memory of visually perceived figures (to the extent, that is, that memory is measured by reproductive accuracy)

The drawings of Grade 5 were studied with the specific purpose of determining which were more similar to the objects named by the experimenter (1) the stimulus figures to which those names had been applied, or (2) the drawings which the subjects had made of the figures For example, which was more like a hat, the figure which the experimenter had said resembled a hat, or the reproductions which the subjects had made of that figure? Similarly, which looked more like a ship's wheel, the figure to which the experimenter had applied that name, or the drawings which the subjects had made of it? When the two raters failed to agree in their judgments of a given drawing, recourse was had to the third experimenter, whose decision was accepted

In the same way, the drawings assigned to Grades 2, 3, and 4 were studied, in order to determine whether these reproductions were more or less similar to the objects named than were the stimulus figures themselves

RESULTS

1 Table I gives the number and per cent of the drawings, made by the subjects of Groups A and B, which the experimenters assigned to each of the five grades of the rating scale.

Thus, 26 per cent of the 3,495 drawings were classified in Grade 5, and 91 per cent were referred to the three lowest ranks of the rating scale Grades 4 and 5 together received 62 per cent, whereas Grades 1 and 2 together received only 9 per cent

2 When the 905 reproductions of Grade 5 were studied for the degree of their resemblance to the objects named in Word Lists I and II, the results presented in Table II were obtained

As Table II shows, almost 75 per cent of these drawings looked more like the objects named than did the original stimulus figures It is of especial interest to note the manner in which the different names given by the experimenter in Word Lists I and II produced corresponding differences in the reproductions When figure 10 had been called a "pine tree," 86 per cent of this group of drawings resembled a pine

TABLE I

The Number of Drawings Assigned to Each of the Rating-scale Divisions, for Groups A and B

Scale of grades	Number of reproductions	Per cent of the total number
1	26	1
2	285	8
3	1,011	29
4	1,268	36
5	905	26
Total	3,495	100

tree more than the stimulus figure did But of the reproductions which were made of the same figure after it had been called a "trowel," 100 per cent were more trowellike than the stimulus In the same way, the proportions of the Grade 5 drawings of stimulus figure 2 which resembled a "bottle" or a "stirrup" more than did the figure were 100 per cent and 69 per cent, respectively, depending upon which of these names the experimenter had applied to the figure A study of Table II reveals comparable findings for each of the other 10 stimulus figures It is, therefore, clear that when a subject reproduced a stimulus figure very inaccurately, his drawing tended to be similar to the object which the experimenter had named when the figure was presented Figure 44 shows a number of examples of the way in which the drawings distorted the stimulus figures in the direction of those objects

Of the Grade 5 drawings of the Group C subjects (to whom the ex-

perimenter had given no names in connection with the stimulus figures), 45 per cent showed a fairly marked resemblance to the objects named for Groups A and B This percentage is considerably smaller than the corresponding percentages for Groups A and B (74 and 73, respectively)

The authors report that a subsequent study of the reproductions ranked in Grades 2, 3, and 4 revealed similar relationships, although in a less marked degree, between the character of the drawings and

TABLE II

The Per Cent of the Reproductions of Grade 5 Which Surpassed the Stimulus Figures in the Degree of Similarity to the Objects Named (Groups A and B)

Stimulus figure	Per cent of reproductions	
	Word List I	Word List II
1	47	78
2	100	69
3	65	48
4	69	75
5	45	81
6	87	94
7	54	47
8	83	100
9	90	63
10	86	100
11	76	85
12	87	40
Average	74	73

the objects named by the experimenter (The percentage values for these three grades are not presented in the original report of the experiment)

DISCUSSION

The results of the experiment by Carmichael, Hogan, and Walter clearly demonstrate how language may influence the reproduction of visually perceived forms in striking ways This finding is in agreement with the results of previous experiments[1] in which it was discovered

[1] Wulf, F Beitrage zur Psychologie der Gestalt VI Ueber die Veranderung von Vorstellungen (Gedachtnis und Gestalt) *Psychologische Forschung*, 1921, vol 1, pp 333–373

Gibson, J J The Reproduction of Visually Perceived Forms *Journal of Experimental Psychology*, 1929, vol 12, pp 1–39

that subjects often *spontaneously* identified the stimulus figures with various concrete objects, that this identification involved naming the objects, and that this naming apparently influenced the character of the subsequent reproductions Furthermore, it had been found that, even when the stimulus figures did not suggest concrete objects, the figures frequently were verbally described by the subjects "to them-
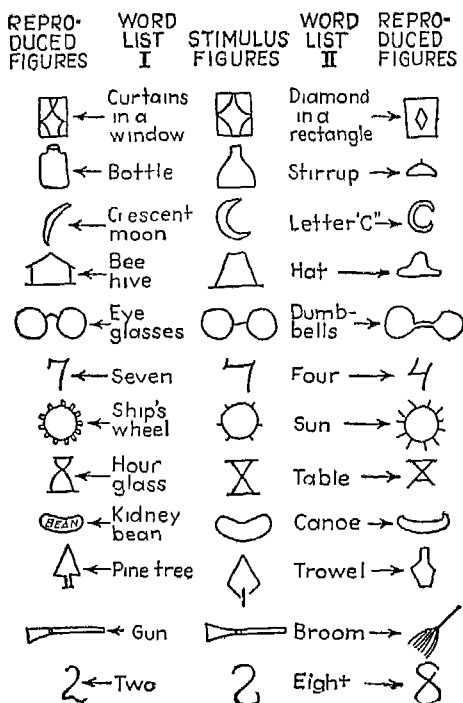
FIG 44 The Stimulus Figures and Examples of Reproductions Which Conformed to the Visual Representations of the Object-names of Word Lists I and II

selves," and the later reproductions showed changes in harmony with the descriptions Thus, if the subject himself had termed a stimulus figure "symmetrical," or "rounded," or "Gothic," the drawing which he made commonly exaggerated the trait [1] In this connection it is

[1] Gibson writes that alterations in the reproductions often seemed to be determined by "cues from a verbal analysis which was made of the forms [by the subjects] during perception" *Op cit*, p 39

interesting to consider the fact that 45 per cent of the Grade 5 reproductions of Group C resembled the objects named in Word Lists I and II more than did the stimulus figures It is highly probable that a considerable number of these reproductions were influenced by spontaneously perceived and named similarities between the stimulus figures and the objects which they resembled (the objects which were explicitly designated for Groups A and B by Word Lists I and II, respectively)

Evidence from many sources suggests that the influence exerted by language on memory and perception is not restricted to such material as visual diagrams The lawyer's trick of asking uncertain witnesses leading questions is a familiar application of the principle "What color was the overcoat which the accused was wearing?" may cause a witness to "remember" a coat which in actual fact never existed Similar instances in direct perception might be cited For example, the excited whisper, "There's a deer I can see him move!" may cause the hunter to take careful aim at a motionless stump Such facts provide reason for wondering whether Shakespeare's opinion that "A rose by any other name would smell as sweet" is a valid dictum Surely, it is not substantiated by experiences such as the shift in a person's feeling tone as he realizes that what someone has pointed out to him as a large and luminous "moon" is merely a prosaic street lamp Without question, the word which is applied to a stimulus object strongly influences the nature of the perceptual response to that object

The conclusion that words influence what we perceive and what we remember is of great importance for the study of man's thought processes No normal person creates his own words in order to symbolize his own experiences For such purposes, we accept the words of the particular language we speak and interpret new experiences in terms of those words In consequence, everything we perceive is influenced, not only by what *we* have previously perceived, but also by what *the society into which we are born* has perceived and has formulated into language symbols People of some nationalities are taught that a certain group of stars is the "Great Bear", others are informed that the same constellation is the "Big Dipper" If the results of the present experiment are generally valid, it must be supposed that those who call it "The Bear" see and remember it as more like a bear than do those who call it "The Dipper"

In our own society there are many instances in which different kinds of behavior are aroused toward an object when different words are applied to it. The recognition of this fact is exemplified by the attempt to "dignify" certain vocations, *i e*, to win an attitude of greater public respect toward them, by the simple expedient of changing their names. One does not regard a house handyman with the awe which a "dwelling engineer" elicits, one is more likely to engage a room in a "hotelette" than in a rooming house. Similarly, we now have "sanitary engineers" (garbage men), "appearance engineers" or "tonsorial artists" (barbers), "demolition engineers" (house wreckers), "sleep engineers" (bedding manufacturers), "morticians" (undertakers), etc. If we had never encountered either flower and were given the choice of planting a "thorn apple" or a "stinkweed" in our garden, most of us would unhesitatingly select the former, although both are names for the same plant.

The comparative study of languages strengthens this argument. In many cultures there exist language distinctions which to us seem unnecessary or even unintelligible. Eskimo languages contain separate words for "snow on the ground," "snow heap," "falling snow," "drifting snow," "soft snow," etc. The fact that we have but one word for all these varieties of snow may be the reason why we often fail to perceive slight differences in snow which would be immediately obvious to Eskimos and which they would designate by different words. Conversely, language distinctions which seem inevitable to us may be ignored in languages which reflect a very different type of culture. Thus, in some languages, it would be impossible to express the difference which we perceive between "manslaughter" and "murder," because the underlying legal philosophy which determines our use of these terms is wholly absent in certain societies.

In other words, if we used a different vocabulary or if we spoke a different language, we would perceive a somewhat different world.

Of course, the distinction which we draw between the concepts "manslaughter" and "murder" was not created because of the existence of different words. The different words were themselves created because as a society we had come to differentiate and had taught our children to differentiate between these modes of inflicting death. If we should cease to respond in different ways to these two types of situation, it is probable that one of the words would sooner or later

disappear from general use The people of the sixteenth century were tremendously interested in hawking, and, in order to aid themselves in distinguishing different types of hawks, they used such terms as "peregrines," "tercels," and "merlins," to designate the varieties of the bird The sport has passed out of fashion, and, although we still see the same birds, the one word "hawk" suffices for them all

Conversely, the inception of a new activity or interest which demands a more delicate perceptual analysis is accompanied by an increase in vocabulary Even though such interests or activities may *create* no new objects, every such development carries with it a multitude of new words, not because of an increasing keenness of sense, but because of the need for making finer discriminations One must learn many new names of colors if one is to become a clothing stylist many new names of trees to become a forester Lack of the words operates as a positive hindrance to the performance of the necessary perceptual processes, in the sense that numerous and fine distinctions are missed if one does not have the words with which to label them Possession of the different terms, on the other hand, helps to make the distinctions obvious and easily remembered

Thus, the demands of the society in which we live have created a language to which our perceptions, memories, and thoughts must be adapted Hence, our perceptual, memory, and thought responses are poured into the mold of a system of symbols which has been imposed upon us by society That we rarely, if ever, have thoughts which transcend the confines of our vocabulary is a tribute to the efficacy of the binding and congealing power of language, as expressing a particular culture pattern

II INVESTIGATIONS OF THE EFFECT OF ATTITUDES UPON PERCEPTION AND MEMORY

The experiment discussed above provides a clear demonstration of the general proposition that the way a person perceives and remembers things depends not only upon the characteristics of the things themselves and of the person's recording mechanisms but also upon the particular psychological condition of the person at the time the perception takes place This study shows that the language symbols used in designating an object of perception, by setting up a specific expectation in the subject, can influence the way in which he remembers that object.

More recently, numerous investigations have been directed at a study of various other factors stemming from the individual's past experience which may affect his perception and memory, especially the attitudes which he has developed as consequences of this experience Among the factors which have been studied are the individual's wants and "values," his conception of his place in the world, his ideas of prestige, his racial prejudices, his attitude toward religion, and so on These factors can be subsumed under such terms as "attitudes," or "frames of reference "[1]

Bruner and Goodman,[2] for example, attempted to discover whether the perception and memory of the size of an object are affected by the value or desirability of the object to the person seeing and remembering it These investigators made use of an apparatus designed to permit the subject to adjust the size of a circular patch of light appearing on a ground-glass screen so as to make it equal in size to any one of a number of objects which the experimenter successively named for him or showed him The objects which the subjects were asked to match in size were the United States coins of the five denominations from the cent to the half dollar inclusive The subjects of this research were ten-year-old children, one group consisting of 10 children of poor socioeconomic background (drawn from a settlement house in a slum area), another group consisting of 10 children of relatively wealthy families (selected from a school attended by the children of prosperous business and professional people) Each child of these two groups was tested individually He was asked to estimate from memory, one after the other as the experimenter named them, the sizes of a cent, a nickel, a dime, a quarter, and a half dollar The subject made each estimate (or judgment) by adjusting the circular patch of light until he was satisfied that its size was the same as that of the designated coin It was found that the "poor" children tended to overestimate the size of the coins to a significantly greater degree than did the "rich" children, that is, the "poor" children tended to make the matching circular patches of light larger than the "rich" children did[3]

[1] The term "frames of reference" means the *standards of judgment* by which we perceive and interpret particular situations and events

[2] Bruner, J S, and C C Goodman Value and Need as Organizing Factors in Perception *Journal of Abnormal and Social Psychology*, 1947, vol 42, pp 33–44

[3] This finding of Bruner and Goodman has been confirmed in a more recent experiment by Carter and Schooler on a larger number of subjects, in which a similar apparatus and

This more emphatic tendency on the part of the "poor" children to overestimate the size of the coins is interpreted by Bruner and Goodman as deriving from the fact that the "want" or "need" of these children for the coins was more intense than was that of the well to do The more the children wanted the coins, the larger they remembered them to be According to these authors, if we value an object, one result is that our perception and memory of it are accentuated, or characterized by an increased vividness In other words, our attitude (our "state of readiness to react") toward a highly valued object tends to magnify it in recollection, and perhaps in direct perception as well

Perhaps a similar psychological principle lies behind the tendency of painters and sculptors to portray heroic characters in "heroic" proportions—that is, as large as possible—as though that which is grand inevitably is huge as well The use of the expression "great" as equivalent to "good" or "excellent" is probably another illustration of the principle In other words, our very language "magnifies" what we approve of If certain of the conclusions of the Bruner and Goodman study, as confirmed by that of Carter and Schooler, are generally valid, the fisherman who exaggerates the size of the trout he has caught may not be "lying" but rather giving an accurate report of his memory—even if not of the fish

Another experiment on this general subject is that of Marks,[1] who investigated the influence on perception exerted by the individual's attitude toward his own place in the social environment Negro students were asked to rate their own skin color and that of their classmates on an eight-point scale, from 0 (very dark) to 7 (very light) They were also asked to indicate on the scale the color which they themselves would prefer to be The results showed that the students'

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procedure were used (Carter, L F , and K Schooler Value, Need, and Other Factors in Perception *Psychological Review*, 1949, vol 56, pp 200–207) However, the results of this later study do not corroborate another finding reported by Bruner and Goodman, namely, that the *direct perception* of the sizes of the coins also was more exaggerated by the poor than by the rich children That is, in the experiment of Bruner and Goodman—but not in that of Carter and Schooler—the poor children tended to make the matching circles of light larger than the rich children did, even when *the coins were actually present* so that the sizes of the circles and the coins could be directly compared Further investigation of the problem should reveal the basis of this difference in results

[1] Marks, E S Skin Color Judgments of Negro College Students *Journal of Abnormal and Social Psychology*, 1943, vol 38, pp 370–376

judgments of the color of others were markedly influenced by their own colors. Typically, the dark student tended to exaggerate the degree of lightness of classmates who were lighter skinned than he, just as the light student tended to exaggerate the degree of darkness of companions who were darker than he. Hence, the darker students tended to perceive a given classmate as lighter than did the lighter students, and vice versa. In their rating of their own skin color, the subjects generally judged themselves to be either the shade they had stated they wanted to be, or a shade between that preferred shade and the shade assigned to them by the other subjects. In the latter case, the response appears to represent a compromise between the individual's desires and the objective fact. This study demonstrates how differences in an individual's attitude, in this case toward skin color, can actually bring about differences in the manner in which he perceives his own skin color and that of other persons.

The effect exerted upon perception by ideas of prestige is shown in an experiment in which the investigator asked a number of college students to describe 6 of the 10 standard Rorschach ink blots.[1,2] To half of these students he had given the spurious information that professional men and businessmen tended to interpret the blots as wholes and frequently saw animals in them, while skilled laborers and workers on government relief projects analyzed the blots into details and tended to see inanimate objects. Information, equally spurious, ascribing the opposite tendencies to the two occupational groups had been given to the other half of the subjects. The results plainly showed that the two groups of students reacted to the blots very differently, since the members of each group described them in the manner they believed characteristic of the members of occupations which they held in high social repute and to which they evidently wanted to belong. Thus, the experiment shows that another variety of attitude—in this case, toward certain kinds of occupation—can modify what subjects perceive in the ambiguous Rorschach ink blots.

Other studies show that prejudicial attitudes of various kinds, including racial, religious, and political ones, also affect perception and

[1] Coffin, T. E. Some Conditions of Suggestion and Suggestibility: A Study of Certain Attitudinal and Situational Factors Influencing the Process of Suggestion. *Psychological Monographs*, 1941, vol. 53, No. 241.

[2] The Rorschach test is briefly described in Chap. XXV.

memory For example, one investigator,[1] by means of a questionnaire, ascertained the nature of attitudes toward Negroes of a group of 400 students in two New York colleges The 200 subjects who revealed the most extreme positive or negative attitudes were shown 15 photographs of Negroes and 15 of white people After an interval, the subjects were given the task of trying to pick out the 30 photographs which they had already seen from a total of 46 pictures The results showed that the "anti-Negro" group in both colleges recognized significantly fewer pictures of Negroes than did the "pro-Negro" group The author concludes that "Unfavorable attitude toward the Negro tended to obliterate recognition of individual differences among Negro pictures, whereas favorable attitude tended to heighten recognition of these differences" (page 61) In another part of the same study, Seeleman showed her 200 subjects 28 new photographs, half of them representing Negroes and half white persons Each photograph had a caption, briefly characterizing the persons pictured, either in complimentary or in uncomplimentary terms (*e g*, "always a good sport," or "conceited and always boasting") The "anti-Negro" group remembered significantly more unfavorable characterizations of Negroes, and remembered them in more correct association with individual Negro photographs than did the "pro-Negro" group The results of this experiment strikingly demonstrate how the kind of attitude that we term "race prejudice" can both reduce one's ability to recognize individual members of the less respected race, and increase one's ability to recall facts which are unfavorable to them and therefore harmonious with the prejudicial "frame of reference"

Other studies have demonstrated that women tend to remember more items favorable to women, while men tend to remember more items favorable to men,[2] that a person's theological attitudes in part determine what he will remember of material concerning atheism and theism,[3] that the political sympathies of college students affected their ability to recognize items in a speech they had heard about Roosevelt's

[1] Seeleman, V The Influence of Attitude upon the Remembering of Pictorial Material *Archives of Psychology*, 1940, No 258

[2] Zillig, M Einstellung und Aussage *Zeitschrift fur Psychologie*, 1928, vol 106, pp 58–106

[3] Watson, W S, and G W Hartmann Rigidity of a Basic Attitudinal Frame *Journal of Abnormal and Social Psychology*, 1939, vol 34, pp 314–336

domestic program[1] It has also been demonstrated that perception and memory vary with such influences as reward and punishment,[2] emotional stress,[3] and various kinds of experimentally induced suggestion[4]

Conclusions

The experiments described in this chapter tend to support the popular observation that people tend to "see" what they expect to see, or what they want to see Their perception, and consequently their memory of events, is clearly influenced by their expectations, their habitual modes of thought, their backgrounds, prejudices, estimates of themselves, and so on Indeed, one means of recognizing individuals with unusual systems of habits and ideas, in particular, the extreme types possessed by psychotics, is by the deviation of their perceptions and memories from those of normal people The psychotic, though enjoying normal auditory capacity, may not hear what other people hear, he may hear what other people do not hear (for example, angels talking to him), he may hear things in ways very different from those of most ordinary people (for example, he hears behind him the footsteps, not of another pedestrian, but of an unknown enemy who seeks his life)

Among normal people, however, there are evidently limits to the influence which an individual's own personal experiences and attitudes can exercise upon his perceptions Cherished pet to the child, common cur to the dog fancier, the same animal is perceived as "dog" by both It should be recalled that the chief object of the investigations reported in this chapter was to study the influence of individual experience upon perception and memory, and that most of the studies were ac-

[1] Edwards, A L Political Frames of Reference as a Factor Influencing Recognition *Journal of Abnormal and Social Psychology*, 1941, vol 36, pp 34–50

[2] Proshansky, H, and G Murphy The Effects of Reward and Punishment in Perception *Journal of Psychology*, 1942, vol 13, pp 295–305

Shafer, R, and G Murphy The Role of Autism in a Visual Figure-ground Relationship *Journal of Experimental Psychology*, 1943, vol 32, pp 335–343

Haggard, E R, and G J Rose Some Effects of Mental Set and Active Participation in the Conditioning of the Autokinetic Phenomenon *Journal of Experimental Psychology*, 1944, vol 34, pp 45–59

[3] Postman, L, and J S Bruner Perception under Stress *Psychological Review*, 1948, vol 55, pp 314–323

[4] Sherif, M A Study of Some Social Factors in Perception *Archives of Psychology* 1935, No 187

cordingly planned so as to give the greatest possible scope to such influence For example, the Carmichael figure that was remembered as a "7" or as a "4," depending upon which word was associated with it, was objectively a compromise between a "7" and a "4" There is evidence that, had the figure not been a compromise, *i e*, had it been unmistakably a "7" or a "4," Carmichael's results would have been less striking [1] Yet studies such as those reviewed in the present chapter provide convincing evidence that the differences in past experiences, which differentiate people either momentarily or characteristically, bring about corresponding differences in their perceptions and their memories

It is also worth pointing out that studies of this type are of especial interest to the social psychologist In any complex society, significant differences in the life histories (*i e*, the previous experiences) of its members are likely to result from differences in racial and national origin, socioeconomic status, political and religious affiliations, and so on It is evident that such differences in experience intimately influence the development of differences in attitudes, in wants, needs, interests, prejudices, and the like, so that large groups of persons within the population may differ from other groups in these respects What psychologists have recently discovered is that the attitudes characteristic of different groups within a society tend to produce measurable differences in the perceptions and memories of the individuals who belong to them Thus, whether a person is white or colored, rich or poor, Democrat or Republican, communist or anticommunist, religious or atheistic, tends in some measure to affect—to alter or even to distort—his perception and memory of objects and events in the world about him [2]

[1] See Luchins, A S Social Influences on Perception of Complex Drawings *Journal of Social Psychology*, 1945, vol 21, pp 257–273

[2] The influence of attitudes and similar psychological processes in producing individual differences in behavior has been noted in several other chapters of this book, *e g*, in connection with a person's belief or nonbelief in the occult (Chap I), his susceptibility to motivation by competitive and by cooperative incentives (Chap IV), the probability that he will be able to recall more tasks that he has finished or more that he has had to leave unfinished (Chap V), his behavior in intelligence-test situations (Chap XIV), the likelihood that he will be conditioned (Chap XV), the nature of his perception of the vertical (Chap XXI), and the character of his projective responses (Chap XXV)

CHAPTER XXIII

"DIRECTION" AND THE "SOLUTION CONSCIOUSNESS" IN REASONING

Introduction

Many psychologists who have studied human behavior in problem situations conceive of the problem-solving process as one which requires the proper *selection* of the element or elements necessary for the accomplishment of a given task. Suppose, for instance, that a camper must light a fire but can find no matches. Solution of the problem requires that he *select* for performance one particular group of actions rather than another. Praying for matches to rain down from the skies will not get him very far, nor will going to sleep or walking around in circles. But if he thinks of using his flashlight lens to focus the sun's rays on some inflammable material, he has selected a very promising set of elements for the solution of the problem.

The process by which the correct selection is made is commonly understood to involve two mechanisms: (1) *trial and error*, and (2) *association by similarity*. By *trial and error* is meant the random movements of a baffled organism, "random" in the sense that they are inefficient and unregulated so far as the problem is concerned. The organism is forced into action by the stimulation of a need (*e.g.*, hunger). If in this crucial situation food is not available, the organism responds first in one way and then in another, each "try" being followed by failure. Eventually, however, a movement or group of movements may be made which results in the removal of the stimulus (in our example, cessation of the hunger pangs). Here the correct selection has occurred by a chance discovery. If the situation should recur, and if the animal is capable of learning or thinking, the successful response is likely to appear more readily. After many repetitions of the situation, such an animal will make the proper response promptly.

Association by similarity[1] means the reproduction in a new situation

[1] Many psychologists regard association by similarity as an instance of stimulus gen-

of responses formerly made in another situation to which the new one is similar. The camper in the illustration given above may never have used his flashlight in order to make a fire. But if, in his present need, he thinks of the physics class exercise of using a magnifying glass to create a hot point, and sees how the same end may be attained by means of a flashlight lens, he has made the correct selection through association by similarity.

In their application to problem solving, trial and error and association by similarity provide two ways in which the proper selection of responses may be achieved. Either the solver makes many random movements which fail and eventually hits upon the right ones by chance, or he recalls the responses which he made to a similar situation in the past and applies them in the present setting.

However, Maier,[1] one of the leading investigators of problem-solving behavior, is of the opinion that *selection* of the proper responses is not the whole, nor even the most essential, part of problem solving. Maier does believe that in order to solve a difficult problem, the right part-responses must be selected. But, in addition, one must have the right slant, or approach, or as Maier calls it, *direction*. If the right direction is lacking, the correctly selected part-responses alone cannot furnish the solution. For example, one may know the English equivalents of every word in a Latin sentence and still be unable to translate the sentence as a whole. One has all the necessary part-responses, but the problem cannot be solved because of the absence of the right direction. Under these circumstances, however, the reading of the sentence or two preceding the difficult one may furnish a general way of understanding, *i.e.*, a direction as to the general meaning of the problem sentence. If this direction is the right one, the part-responses will be integrated into the correct pattern and the translation will now be possible. According to Maier, it is the right direction which furnishes the means for making the proper arrangement and organization of the correctly selected responses. So long as the subject working on a problem has no direction, or a wrong one, he cannot reach a solution.

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eralization, a concept discussed in connection with conditioning in most textbooks in introductory psychology.

[1] Maier, N. R. F. Reasoning in Humans. I. On Direction. *Journal of Comparative Psychology*, 1930, vol. 10, pp. 115–144.

I. "DIRECTION" IN HUMAN REASONING[1]

PURPOSE

The aim of the present experiment was to find out whether or not the selection of the correct part-responses alone is sufficient for the solution of a problem

METHOD

The Problem to Be Solved. The subjects were given four poles, a number of clamps, lengths of wire, and pieces of chalk They were asked to construct with these materials two pendulums which might be swung in such a way as to make chalk marks at specified points on the laboratory floor The only solution which would actually work was the following The two pieces of wire were attached to opposite ends of one of the poles To the free end of each of the pieces of wire was tied a clamp Each clamp grasped a piece of chalk Two other poles were clamped together to form a single length, a fraction of an inch less than the length necessary to span the distance from floor to ceiling The pole carrying the two wire-clamp-chalk appendages was laid flush with the ceiling and was held in place by the double pole pressing up against its center The double pole was thus wedged between the floor and the center of the pendulum pole The completed structure looked like a T with the pendulums hanging from the tips of the horizontal bar

The experimental materials presented to the subject are shown in Diagram *A*, and their correct combination for the solution in Diagram *B* of Fig 45

The Part-responses and Direction. This solution process Maier divided into three parts (1) the chalk-clamp-wire arrangement, (2) the process of making a long pole by means of two short ones clamped together, and (3) the wedging of the horizontal bar against the ceiling by the vertical bar To certain subjects he accordingly gave the following *preliminary demonstrations* which were designed to supply the three part-responses necessary for the solution of the problem He showed the subject (1) how to make a plumb line out of a cord, a clamp, and a pencil, (2) how to make a long rod out of two short rods and a clamp; (3) how to hold a bar against the vertical edge of a door-

[1] Adapted from *ibid*

way by wedging against the middle of the bar another bar which reached exactly to the opposite vertical edge, the completed structure resembling a T laid on its side The proper application and combina
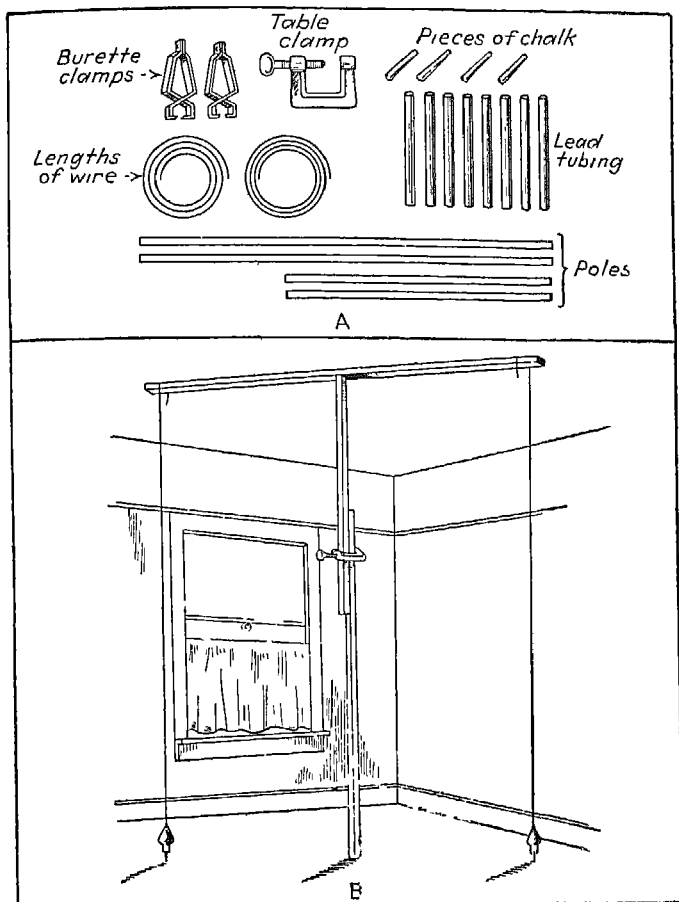
FIG 45 The Pendulum Problem
Diagram *A*, the materials available to the subject Diagram *B*, the correct solution

tion of the three demonstrated principles should provide the solution of the pendulum problem

When the *proper direction* was to be given, the experimenter said, "I should like to have you appreciate how simple this problem would

be if we could just hang the pendulums from a nail in the ceiling Of course, that is not a possible solution, but I just want you to appreciate how simple the problem would be if that were possible " By this observation Maier hoped to direct the subject's attention to the fact that hanging something from the ceiling was an essential feature of the solution

Subjects. The subjects were 84 college students

Procedure. The subjects were divided into five groups Each of these groups received from the experimenter its own set of instructions which differed from those of the other groups in some critical way The experimenter gave these instructions after he had presented the problem but before the attempts at solution were begun The subjects of Group A, before they began their task, were provided with the right part-responses for the problem (*i e* , they were given the preliminary demonstrations) and were told that the part-responses comprised everything that was necessary for the solution None of these subjects had to *select* the correct part-responses, since the appropriate selection was determined in advance by the experimenter A second group, Group B, was given not only the part-responses (*i e* , the demonstrations) but the correct direction, as well If it were found that Group A did as well as Group B, then one might conclude that direction is not important in problem solving, and that selection is the essential process If many more of the Group B subjects solved the problem, the conclusion would be that selection alone is not sufficient to explain problem solution

Other variations in procedure were introduced for three other groups Group C was given the problem without either preliminary demonstrations or direction The subjects of Group D were given the part-responses, but they were not told that the parts had anything to do with the problem Group E was given only the direction, and not the part-responses

There were 62 subjects in Groups A, C, D, and E combined, and 22 in Group B

RESULTS

Only 1 of the 62 subjects in Groups A, C, D, and E reached the solution, but of the 22 subjects in Group B, 8 were successful

CONCLUSIONS

Neither the selection of the proper part-responses alone (as given to Group A) nor the selection of the right direction alone (Group E) was sufficient to bring about a solution of the problem Solutions occurred when both the proper part-responses *and* the proper direction were present (Group B) Maier suggests that the effect of a given direction is to enable only *certain* groupings of the part-responses to appear In this way, a correct direction acts to *organize* the part-responses correctly, *i e*, in a way which makes possible a solution of the problem

DISCUSSION

This experiment proves conclusively that problem-solving behavior cannot be explained by a mere *selection* of the correct response units In addition to selection, the factor of *direction* plays a critical role This conclusion fits in perfectly with everyday observation of the difficulties we encounter while trying to solve problems Everyone knows enough arithmetic to solve this problem "A frog is trying to climb out of a well 30 ft deep It manages to jump up 3 ft every day, but slips back 2 ft every night How long does it take the frog to reach the top?" Although the mathematics involved is very easy, it may take the reasoner a long time to reach the correct solution He fails because he has developed a habitual mode of procedure, *i e*, a direction, for problems of this sort, largely as a result of much school training and exercise in solving similar problems This habitual direction involves a mechanical application of the principle that to discover how long it takes to progress a specified distance, one divides the total distance to be covered by the distance traversed in a given unit of time Reasoning in accordance with this direction, the solver calculates that if the frog climbs a distance of 1 ft a day, it will take him 30 days to climb 30 ft But the spontaneous and habitual way of approaching this problem happens to be wrong, and therefore the solution achieved as a result of this erroneous direction is also wrong In order to solve the problem, it is necessary for the individual to realize that once the frog has reached the top of the well he will no longer fall back The right direction therefore involves the understanding that by the end of the twenty-seventh day the frog has

climbed to a height of 27 ft., and that he spends the twenty-eighth day in climbing to 30 ft and to freedom Until the thinker realizes that a direct application of the method in which he has been so thoroughly drilled does not satisfy the conditions of the problem, he will not be able to reach the solution

And so it is with many problems The individual knows all there is to know in order to solve a given problem, but he cannot immediately do so, either because he has no direction (no idea or "slant" as to how to combine the part-responses correctly), or because he has an erroneous direction, *i.e.*, he can see a way which *ought* to solve the problem, but for some reason which he cannot understand, the solution will not come that way We have all had the experience of feeling particularly foolish when the solution of a problem we have given up is demonstrated to us We say it was really very simple, we knew everything that was necessary for the right answer, yet somehow we were unable to put the pieces of our knowledge together into the correct pattern Maier would say that we lacked the right direction which would have brought about the proper organization of the items of knowledge

On the other hand, although the correct direction is essential, it alone will not provide all the conditions for the solution of the problem The part-experiences must also be available to the subject None of the subjects of Maier's Group E, who received the direction but not the part-experiences, was able to solve the problem This point is corroborated in an experiment by Birch [1] He found that chimpanzees, who had been carefully observed from the time of their birth and had never made any spontaneous use of sticks as reaching tools, were unable to solve a problem which required such a use of sticks for its solution But after a period of three days, during which they were given sticks, played with them spontaneously, and in the course of such play came to use them as a prolongation of the arm, they were able to solve the problem without difficulty Not only the direction, therefore, but the part-experiences as well were necessary for solution to occur As Birch states,

> Once the animal has learned to use the stick as an extension of its arm-reach, it is capable of utilizing this knowledge in a wide variety of ways *This ability to reorganize previous experiences in accordance with the requirements of a new*

[1] Birch, H G The Relation of Previous Experience to Insightful Problem-solving *Journal of Comparative Psychology*, 1945, vol 38, pp 367–383

problem-situation is the essential feature of problem-solving The ability to select from the available repertoire of recall and reorganize into new patterns of response previously learned items of experience, makes possible an enormous expansion of the adjustive possibilities of an organism (pages 381–382)

But Maier does not attempt to tell us under what conditions the correct direction appears If, as he says, one may have a right or a wrong direction in any problem, then one must be able to select the right one in order to be successful How *this* selection is achieved Maier does not explain It is difficult to believe that the factor of direction itself is independent of selection through trial and error, or through association by similarity [1]

II THE ROLE OF WRONG DIRECTIONS IN HUMAN REASONING[2]

PURPOSE

In the first section of this chapter we explained the meaning of Maier's concept of *direction* The results of Maier's first experiment showed that, in many cases, the subjects failed at first to solve the problem because they started out with the wrong direction, *i e* , they approached the problem from the wrong angle The results also showed that subjects often adhered obstinately to a wrong direction, in spite of their repeated failure to solve the problem under its guidance

In the present experiment, Maier's purpose was to find out whether this wrong direction is an active factor which *prevents* the appearance of the right one, or whether it persists merely because the right direction does not appear

[1] An experiment in which Maier's pendulum problem was presented to a group of college students has been performed by Weaver and Madden Perhaps because of certain differences in conditions, the authors of this investigation obtained results which differentiate less clearly than those of Maier's study between subjects who had received the part experiences plus the direction, and subjects who had received the part-experiences only Ten of the fifty-four subjects of this investigation succeeded in solving the problem Of these ten solutions, four were achieved by subjects who had received the part-experiences but not the direction In interpreting these results, the authors do not claim that these solutions occurred without direction Rather, in accordance with Maier's theory, they suggest that the solutions were arrived at through the integration of the experimentally given part-experiences in terms of the correct direction, and that this direction was selected by the subjects on the basis of their past experience (Weaver, H E , and E H Madden "Direction" in Problem Solving *Journal of Psychology,* 1949, vol 27, pp 331–345)

[2] Adapted from Maier, N R F An Aspect of Human Reasoning *British Journal of Psychology*, 1933, vol 24, pp 144–155

METHOD

The method involved observing the effectiveness, as an aid to problem solving, of advice calculated to make the subjects hold less firmly to their first assumptions concerning the solution of a given problem If the advice actually helped to produce solutions, this result would show that the pursuit of a wrong direction is in itself a factor which interferes with successful problem solving If, on the contrary, such advice failed to prove helpful, this finding would indicate that a wrong direction does not inhibit the appearance of the right one, but continues to operate only because the right direction is not present

The Problems to Be Solved. The subjects were given the following three problems

1 *The Two-cord Problem* In this problem the subject was required to tie together the free ends of two cords hanging from the ceiling to the floor The distance between the cords was such that it was impossible to reach one if the other was held Various solutions of the problem were possible One cord might be lengthened One cord might be tied to a chair between the two cords One cord might be pulled in with a pole, while the other cord was held If the subject solved the problem in any of these ways, he was told to look for another solution The solution which the experimenter arbitrarily designated as "correct" was to tie a weight (*e g* , a pair of pliers) to one of the cords and swing it as a pendulum Then the subject would be able to hold the stationary cord with one hand, and with the other hand to reach the swinging cord on its approach movement

2 *The Problem of Making a Stable Hatrack by Means of Two Poles and a Clamp* The solution was to clamp the two poles together so as to make one long pole reaching from floor to ceiling This long pole could then be wedged between floor and ceiling, and the clamp used as a hook

3 *The Problem of Putting Out a Lighted Candle 8 ft Distant from the Subject* Sections of rubber and glass tubing had to be fitted together and the whole kept from sagging by clamping it to a rod The subject would then be able to blow at the candle through the 8 ft tube

The initial arrangements of the experimental materials and their combinations into the correct solutions are shown for problems 1, 2 and 3 in Figs 46, 47, and 48, respectively

Subjects. The subjects were 384 students in an introductory course in psychology. The subjects were divided into an experimental and a control group.

General Procedure. The three problems were presented together at the beginning of the experimental period. The subjects worked
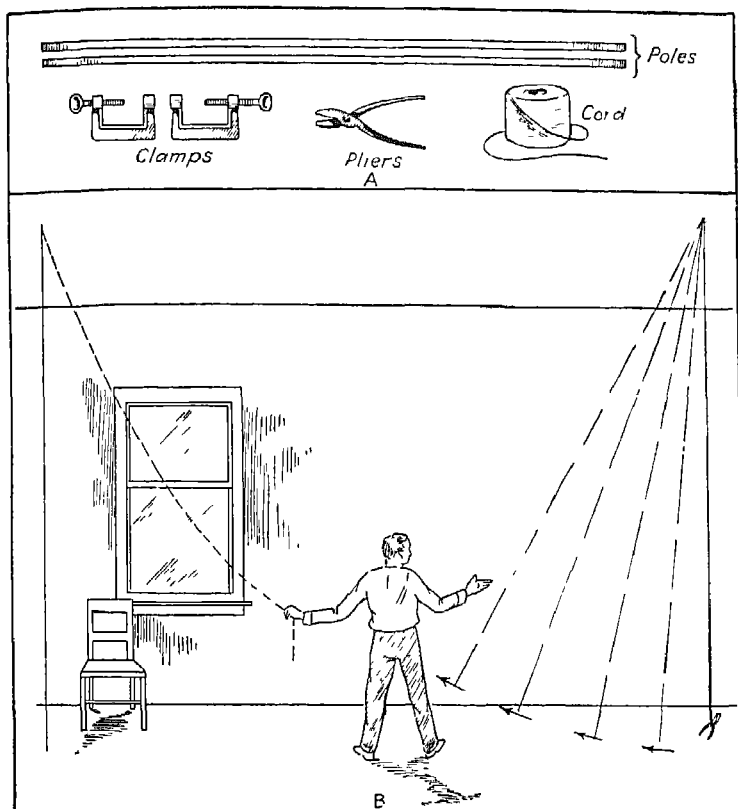
FIG. 60. The Two-cord Problem

Diagram *A*, the materials available to the subject. Diagram *B*, the correct solution.

individually. They were permitted to attack the problems in any order and to study the materials for solving them for as long as they wished. Each student continued to work until he had achieved an acceptable solution for each problem, or until he had worked for a total period of 1 hr. The subjects did not actually manipulate the materials but described their suggested solutions in writing.

Procedure for the Control Condition. The 206 subjects who worked under the control condition were presented with the three problems but were given no preliminary instructions

Procedure for the Experimental Condition. The 178 subjects who worked under the experimental condition were given a preliminary
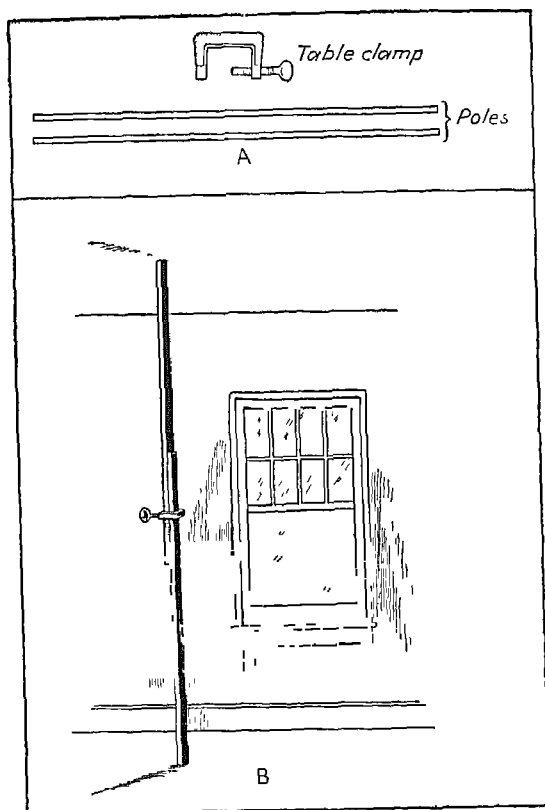
Fig. 47 The Hatrack Problem

Diagram A, the materials available to the subject Diagram B, the correct solution

lecture, lasting 20 min , on the solving of problems, which was then summarized in these hints "(1) Locate a difficulty and try to overcome it If you fail, get it completely out of your mind and seek an entirely different difficulty (2) Do not be a creature of habit and

stay in a rut Keep your mind open for new meanings (3) The solution-pattern appears suddenly. You cannot force it Keep your mind open for new combinations and do not waste time on unsuccessful efforts" (page 147) The problems were then presented
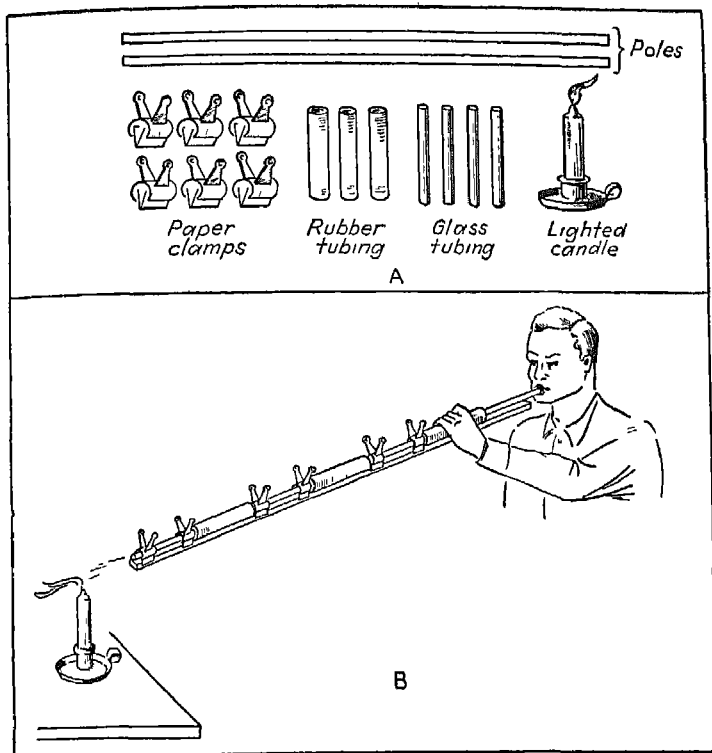
FIG 48 The Candle Problem

Diagram *A*, the materials available to the subject Diagram *B*, the correct solution

RESULTS

The findings are presented in Table I, page 416

As the table shows, more experimental subjects than control subjects solved each of the three problems The difference was greatest for problem 3, the candle problem

CONCLUSIONS

The only difference in the procedure for the experimental and control groups was the introductory instructions which were given to the

experimental subjects. As a consequence, those instructions must have been responsible for the better showing of the experimental group, unless that group was naturally superior to the control in ability to solve problems. In order to test the latter possibility, Maier ran a check experiment in which he compared, not the performance of one group with another group, but the performance of a single group of 169 subjects with and without the preliminary general instructions, on two problems of equal difficulty. Since this group as a whole scored twice as many solutions *after* it was given the instructions as before, there seems little doubt that the superior performance of the experimental group in the main experiment can be explained in terms of the effects of the experimenter's lecture warning against a "one-track" approach.

Table I

Showing for the Control and for the Experimental Conditions the Percentage of Subjects Solving Each of the Three Problems

Condition	Number of subjects	Per cent of subjects solving		
		Problem 1	Problem 2	Problem 3
Experimental	178	50.6	28.7	68.3
Control	206	49.0	22.3	47.8

Maier concludes that (1) ". . . persistent [wrong] directions which accompany problem-solving actually prevent solution-patterns from appearing"; (2) ". . . reasoning is, at least in part, the overcoming or inhibiting of habitual responses" (page 153). By "habitual responses" Maier means the wrong direction which the solver first pursues.

DISCUSSION

The foregoing experiment emphasizes the danger of remaining too stubbornly fixed in a single direction when one is trying to solve a problem. Sometimes, the solution to a problem lies under one's very nose, so to speak, yet it is not grasped because one is intent on something else (*i.e.*, one has organized the field in an incorrect way). Although a flashlight lens, a blazing sun, and dry tinder may all be present, it is possible that a concentration on the search for matches occupies the camper so completely that he never thinks of lighting a fire by means of the lens. Maier's preliminary instructions to his subjects made them somewhat skeptical of the directions from which they first attacked the problems and made them more receptive to new

angles of approach The instructions were, therefore, helpful in the solution of such problems as Maier presented, since in each of them, the usual (*i e*, the "habitual") direction was a wrong one, and the solution came easily and immediately when the right direction was taken

But it must be pointed out that Maier's instructions may not prove helpful in *all* task situations In some situations, the "habitual" direction may be the right one, even though it does not immediately lead to the solution Perhaps the camper's matches are actually to be found in some obscure corner of his knapsack If the camper gives up the search too quickly, he may never find them, and if, in addition, he fails to think of using the lens of his flashlight, he may have to eat his food raw

Maier probably would not call the process of finding the hidden matches "problem solving," since he believes that only situations which require the arousal of new (*i e*, "unhabitual") directions for solution may properly be described as "problems" Nevertheless, discovery of the matches adjusts the camper's difficulties and satisfies his need However, the question as to what is and what is not a "problem" is irrelevant to the value of Maier's instructions in *task* situations A motivated individual does not know beforehand whether the direction which he first follows, if pursued assiduously enough, will lead sooner or later to the goal, or whether in order to achieve it he will have to abandon the original direction and adopt a new and unusual one If the situation happens not to be of the kind which Maier calls a "problem," the pursuit of Maier's instructions, instead of aiding, might actually interfere with the attainment of the goal In such situations, an individual who remained intent on his first and "habitual" direction would do better than one who was too ready to shift his method of approach However, it is surely true that the following of Maier's instructions in situations which he characterizes as problems would facilitate the achievement of the solution

III THE APPEARANCE OF PROBLEM SOLUTIONS IN CONSCIOUSNESS[1]

PURPOSE

In the investigation of human reasoning it is frequently found that, when subjects have completed the solution of a problem, they are

[1] Adapted from Maier, N R F The Solution of a Problem and Its Appearance in Consciousness *Journal of Comparative Psychology*, 1931, vol 12 pp 181–194

unable to tell the experimenter just how the solution was attained In fact, they are often unable to supply any information at all about the processes which led to the solution In response to questions, all they can say is, "I was entirely baffled one moment, and the next moment I had the right idea," or, "The solution just seemed to pop into my head "

Maier wished to discover why people cannot reconstruct the stages by which they achieved the solution of a difficult problem He therefore states the aims of the present investigation in these terms

1 "Does the solution develop from a nucleus or does it appear as a completed whole?" (That is, does the solution pass through a process of development, or, as subjects' introspections suggest, does it appear suddenly and completely formed?)

2 "What is the conscious experience of an individual just before the solution is found?"

3 "Is the reasoner conscious of the different factors which aid in bringing about the solution?" (Page 181)

METHOD

The Problem to Be Solved. The problem was *the two-cord problem*, described in the report of the second experiment Only the "pendulum" solution was accepted The room in which the experiment was carried on contained many objects, such as pliers, clamps, pieces of cord, poles, tables, and chairs In Fig 46, Diagram *A* illustrates the initial arrangement of the experimental materials, and Diagram *B* their combination into the "correct" solution

Subjects The subjects were 116 men and women who were graduate and undergraduate university students These subjects were divided into two groups

Experimental Condition. (61 subjects) If the subjects who worked under the experimental condition failed to solve the problem within 10 min., the following "hints" were given

Hint 1 While walking to the window, the experimenter "accidentally" brushed against one cord, thereby starting it into slight motion If it was noted that the moving cord was not in the subject's line of vision, the action was repeated

Hint 2 The experimenter gave the subject a pair of pliers and told him that with the aid of that tool alone the problem could be solved

Hint 1 was given first If the solution failed to follow within a few minutes, Hint 2 was given If the solution still did not appear, Hint 1 was repeated If this hint failed to prove effective, the subject was shown the solution

Control Condition. (55 subjects) The group which worked under the control condition was not given the hints The subjects worked on the problem for at least 30 min before they were permitted to give up

RESULTS

Experimental Condition.

A 24 subjects (39 3 per cent) solved without the aid of the hints

B 23 subjects (37 7 per cent) solved after the hints had been given

C 14 subjects (23 0 per cent) failed even after receiving the hints

Maier chose subgroup B for analysis, because only in that subgroup could he analyze the role of the artificial aids in producing solutions For 19 of the 23 subjects of subgroup B, the solution followed Hint 1 and not Hint 2 For the 23 subjects the average length of time between the last hint and the solution was 42 sec

According to their statements, the solution appeared *in parts* for 7 of the 23 subjects who solved with the aid of hints For these subjects, the idea of swinging the cord and the idea of attaching a weight to it appeared separately The other 16 subjects produced the solution *as a whole*, that is, these subjects first thought of the pendulum principle and then proceeded to "weight" the cord and to swing it

Of the 7 subjects who solved *in parts*, 6 ascribed the solution to Hint 1 Of the 16 who solved *as a whole*, 15 failed to report the occurrence of Hint 1, when they were specifically asked whether or not they had seen the cord swaying, most were very vague in their answers but insisted that they were unaware of having been helped by the hint

Control Condition. Of the subjects who solved the problem under this condition, 80 per cent solved within 10 min Only 20 per cent of the solutions occurred after that time

CONCLUSIONS

1 In the experimental group, 47 per cent of the successful subjects solved the problem after the initial 10-min period had elapsed. In the control, only 20 per cent of the successful subjects solved it after

10 min This difference shows that the extra working time after the giving of the hints could not have accounted for the increase in solutions following the hints. The short time intervening between hint and solution (an average of 42 sec) also indicates the efficacy of the hint Maier concludes that the hints were effective aids, and describes them as " added elements which make the pendulum organization more readily experienced, just as additional points represent the organization of a circle more readily than three points" (page 191)

2 Those subjects who solved the problem in two steps recognized the aid given by the hint But those who solved it in a single step denied that the hint had helped them The conclusion Maier draws from these reports is that, when the solution appears gradually, the subject experiences the steps by which it comes about, when the solution occurs in but a single step, the subject cannot recognize the process by which it is established Thus, according to Maier, the subjects were not aware of Hint 1 because the sudden appearance of the solution dominated consciousness

Maier summarizes "The perception of the solution of a problem is like the perceiving of a hidden figure in a puzzle-picture In both cases (a) the perception is sudden, (b) there is no conscious intermediate stage" between fruitless efforts directed at solution and the dawn of the solution idea (page 193)

DISCUSSION

This study of Maier's touches on issues which have been little explored by the experimental psychologist It provides a particularly interesting demonstration of the untrustworthiness of introspective reports Maier proved that his hints were a substantial aid to the subjects in achieving their solutions Yet many of the subjects denied that they were helped by the hints, and some were even unable to recall that any hints had been given This observation is corroborated by common experience Ideas which "pop" into our heads without seeming to undergo any growth or development may often be accounted for by some occurrence in the environment which serves as a "cue" or "hint " We can think of the event responsible for the "explosion" of a new idea as a sort of fuse, but the fuse may be blown up in the explosion which it starts, and it may never be found

Everyone has had the experience of struggling long and fruitlessly

toward the solution of a problem which suddenly seems to solve itself If, after the solution has been achieved, we try to recall the way in which we arrived at it, we are frequently unable to shed any light on the process All we can say is that we were pursuing a false "hunch," were "barking up the wrong tree," and that then, all of a sudden, the solution or the way of achieving the solution flashed into being We cannot recapture the steps which intervened between our last futile efforts and the birth of the right idea We can only say that the solution idea was wholly absent one moment and present the next, that at first the various parts or aspects of the problem would not hang together correctly but that this confused state then shifted to an "insight" in which all the parts appeared in their proper interrelationships

Introspection or "self-observation" by adult human subjects in experiments like those by Maier bears out the thesis that the solution of a problem often occurs in a flash (that is to say, by insight), and that such insight frequently appears suddenly and comes about through a process of development which cannot be detected by means of introspection But the fact that one cannot remember what it was that led to the "insight" certainly does not mean that no causal process preceded it To assert that a problem was solved because an insight occurred leaves entirely unsettled the crucial question as to what processes produced the insight

By supplying his subjects with hints, Maier enabled them to produce solutions which they could not have reached without assistance For a large number of the members of the experimental group, the utilization of the hint was the turning point from the pursuit of incorrect efforts at solution toward the dawn of the solution idea Yet few of these subjects acknowledged that they had been aided by the hints, and the majority of them actually appeared to have been unaware of their occurrence

The results of Maier's experiment add to the already considerable fund of evidence which proves that we are entirely unaware of many of the factors which influence our behavior The stimuli, both internal and external, which act on the human being from moment to moment are exceedingly numerous and complex Of these stimuli, we are usually conscious at any given moment of but very few, and sometimes of none at all The result is that when an individual is

questioned as to the causes of some given action on his part, he may be quite unable to explain the behavior in terms of antecedent stimulating factors Or if he thinks he can give a retrospective account of the origin of his actions, his description may deviate widely from the sequence of events which actually occurred Such unconscious falsification may arise in either of two ways (1) the report may be incomplete in the sense that the subject is able to recall some, but not all, of the stimulating factors which actually controlled his behavior, (2) the subject's report may describe only incidental stimuli which had little or no directive effect on the course of his activities, and thus may omit the crucial behavior determinants altogether [1]

The fact that our awareness of why we act as we do is characteristically vague and incomplete constitutes a fundamental objection to the method of introspection in psychological research Many psychologists believe that even in the study of the simplest processes the method of self-observation gives at best but a partial account of the behavior under investigation For example, in one study,[2] subjects were required to determine whether a visually presented symbol was × or + As part of the procedure, the intensity of the illumination of the symbol was at times reduced to a point at which the subject claimed that he could not determine which figure he was seeing, and that his judgments as to its nature were therefore pure guesses One would expect that the percentage of correctness of the subjects' responses under these conditions would be only 50, *i e*, the proportion which would be correct by chance alone But the investigator found that at these levels of stimulus intensity, and even at somewhat lower levels, the percentage of correct judgments was considerably above chance It was only when the intensity of the stimuli was reduced to a point much below the first "guesswork" level that the proportion of correct judgments fell to 50 per cent The same results were obtained when auditory stimuli were used Since all the subjects denied having been aware of stimuli which were proved to have affected their behavior, the study shows how unreliable is the method of verbal report (introspection), even for the study of so relatively simple a process as discriminating between two familiar symbols

[1] As pointed out in Chap I of this book, the field of the "occult" is replete with examples of such errors

[2] Baker, L E The Influence of Subliminal Stimuli upon Verbal Behavior *Journal of Experimental Psychology*, 1937, vol 20, pp 84-100

When we are concerned with processes as complex as those involved in problem solving, the reliability of results which are obtained by the introspective method alone is very questionable Some of the most enthusiastic advocates of introspection have cautioned us not to rely too much upon it as a means of investigating complex forms of behavior Although there are not many psychologists who would repudiate self-observation entirely, it is also true that the great majority insist upon supplementing or replacing it, whenever possible, by observational methods of a more objective sort

CHAPTER XXIV

IMPLICIT MUSCULAR ACTIVITIES DURING THINKING

INTRODUCTION

There are two general theories concerning the physiological basis of thinking. According to the older of these theories, which we may term the "central" theory, processes of thought, reasoning, imagination, or ideation depend upon or are aspects of complex brain activities. The implied assumption is that motor processes are not a necessary condition of thinking, and that thoughts and ideas may run their courses, even in the absence of all motor activities. On the other hand, the somewhat newer "motor" or ("peripheral") theory assumes that processes of thinking, reasoning, or imagining are as much dependent upon motor responses as upon brain action. Thinking, so viewed, is not a correlate or aspect of cortical brain activity alone but is intrinsically a reaction which functions in terms of complete sensori-motor patterns, with the motor part of each circuit just as essential to the process as the central segment is.

A few adherents of the motor theory of thinking have insisted that thought processes are to be identified with activities of the speech mechanisms. According to this view, when a person is thinking, he is "talking to himself" and his vocal organs are active, even though the movements are microscopic and are detectable only with the aid of sensitive instruments. Thinking and imagining are merely "subvocal" talking. Other exponents of the motor theory have proposed broader interpretations, suggesting that thinking may be based upon implicit muscular contractions involving many other muscle groups as well.

Early Experimental Investigations. Prior to the studies which will be described in the following pages, several attempts had been made to test experimentally the role of motor processes in thinking, but the results obtained by different investigators had been somewhat contradictory. Some of the reported results favored the motor theory, but quite as many findings were of a negative sort. In all probability,

these inconsistencies are attributable to the crudity of the instrumental techniques employed and to the lack of adequate experimental controls. In one experiment, for example, a rubber bulb was placed in the front part of the mouth between the teeth and the tip of the tongue and was connected to a recording tambour By this arrangement, slight movements of the tongue exerted pressures on the bulb and such pressures were recorded graphically It was reported that every record obtained during "silent thinking" revealed some movement, and the conclusions drawn was that unconscious movements of the tongue[1] actually take place during thinking But the technique was imperfect, in that the apparatus attached to the tongue was activated by respiration and by swallowing, as well as by tongue movements Therefore, the seemingly positive results cannot be accepted without question, since we have no guarantee that the movements recorded were essential to, or even directly associated with, the thought processes

In another study[2] in which tongue and lip movements were recorded by mechanical means, the response patterns obtained were not the same when the subject was thinking in words "to himself" and when he was saying the same words aloud Moreover, some records showed no lip or tongue movements during silent thought The experimenter concluded that, since lip and tongue movements are not universal in internal speech, and since, when they do occur, they are not always identical with the movements made in pronouncing the same words aloud, thought activities do not necessarily involve motor expression and are probably "intraneural "

However, in criticism of the above experiment and its conclusions, it may be said that mechanical recording systems are not sufficiently sensitive to respond to all the minute components of an implicit pattern of response, and because of their inevitable inertia they are not capable of following effector changes which occur in rapid succession It may be said that many of the weaker elements of a pattern of vocal organ response which would be recorded if the response were overt would lie below the threshold of the instrument's sensitivity when the pattern

[1] Courten, H C Involuntary Movements of the Tongue *Yale Psychological Studies*, 1902, vol 10, pp 93-96

[2] Thorsen, A M The Relation of Tongue Movements to Internal Speech *Journal of Experimental Psychology*, 1925, vol 8 pp 1-32

is reduced to the implicit level Thus, the records would be different even if the patterns of response were actually similar Furthermore, when vocal behavior is reduced to the implicit level, it may become much abbreviated and "short-circuited", that is, it may require a much shorter time and its pattern may be considerably altered in form If this is true, the record of an implicit thought pattern would not be simply a reproduction in miniature of the record of an overt speech pattern, even when the two patterns represented equivalent verbal processes (*i e*, thinking silently in words or saying the same words aloud) Such complex relations between the two records could not be identified by their crude, mechanically registered representations on the smoked drum

Within recent years, however, new *electrical* methods of recording implicit muscular activity have been utilized in the investigation of the motor theory of thinking Certain of the results obtained appear to be somewhat more significant than those secured through the use of less sensitive mechanical devices The experiments of two investigators who used the electrical recording technique will be described in the following pages

I JACOBSON'S EXPERIMENT[1]

PURPOSE

The aims of Jacobson's experiment were (1) to learn something specific about what takes place in the nervous or neuromuscular system during the process of thinking, and (2) as far as possible, to represent these processes in quantitative terms

METHOD

Apparatus. All muscular activity involves changes in electrical potential. The electrical changes which occur, even in minute implicit muscular contractions, may be detected and recorded by means of a system involving electrodes attached to the subject's body in the neighborhood of the muscles concerned, and connected with a very sensitive galvanometer (A galvanometer is a delicate instrument which detects and measures very weak currents of electricity) The currents

[1] Adapted from Jacobson, E The Electrophysiology of Mental Activities *American Journal of Psychology*, 1932, vol 44, pp 677–694

set up by the electrical potentials involved in muscular and neural action are called "action currents"

In the present experiment, an extremely sensitive galvanometer was used in conjunction with vacuum tubes, the latter being employed to amplify the weak action currents Means were provided whereby all deflections of the galvanometer were recorded photographically on a moving film, as a kind of shadowgraph So sensitive was the apparatus that changes in electrical potential as small as one-millionth of a volt could be recorded

Subjects. All of the subjects employed had been trained to proficiency in the act of relaxing the skeletal muscles to an extent such that little more than the minimum tonic tension remained This training in relaxation was very important for the purposes of the experiment because restless movements of subjects who had not been trained to relax would have confused the interpretation of the records We are not informed as to the number, age, or sex of the subjects

Procedure During every test, the subject's eyes were closed and he lay upon a couch in a darkened, quiet, partially soundproof room All possible sources of distraction were carefully excluded The subject was instructed to engage in some stated type of imaginative activity (*i e*, thinking about or performing a particular movement or imagining some specified situation) as soon as he heard the click of a telegraph sounder, and to discontinue the "mental" activity and to relax any muscular tensions present when he heard a second signal click The exact instant at which each click occurred was indicated photographically on the same film upon which the muscular activity was recorded This was accomplished by having an electrically operated bar cast a shadow upon the film each time the sounder was activated

RESULTS

Imagination of Arm Movements. In one series of tests the electrodes were connected with the flexor muscles of the right arm The relaxed subject was told that when he heard the first signal he was to *imagine* bending his right arm and when he heard the second signal he was to relax any muscle tension which might be present During the period of general relaxation preceding the first signal no muscular activity was recorded, the galvanometer recording was a straight line

Within a fraction of a second after the first signal, however, the record began to show large galvanometer swings which persisted until soon after the signal to relax was given The results were the same for 20 subjects tested under these conditions

Six control conditions were imposed With electrodes attached to the *flexors of the right arm*, the subject was instructed, in different tests, (1) to imagine bending the left foot, (2) to imagine bending the left arm, (3) actually to bend the left arm, (4) actually to bend the left foot 1 in , (5) to imagine the left arm perfectly relaxed, or to imagine it paralyzed, (6) to imagine extending the right arm

Negative results were obtained under all the control conditions outlined above, that is to say, no electrical changes in the flexors of the right arm were recorded These negative results ruled out the possibilities (1) that the deflections observed during the imagination of the right arm flexion are due to the effects of the signal sound upon the subject, (2) that the act of imagination which was tested involved action currents all over the body

In other test series, the electrodes were attached to the muscles of the right arm and the subjects were instructed to imagine various acts involving activity of the arm muscles When the instructions were to imagine lifting a 10-lb weight with the right arm, electrical fluctuations were found to occur in that arm during the process of imagining but not during the foregoing and the succeeding periods in which the subject was instructed to relax Positive results were recorded, similarly, when the instructions were to imagine the following acts—acts which the subjects agreed invariably involved the right hand (1) lifting a cigarette to the mouth, (2) pulling a microscope toward one, (3) pulling up one's socks

Positive results were also obtained for the imagination of rhythmical acts, such as climbing a rope, pumping up a tire, grinding coffee, or turning an ice-cream freezer In these tests, the galvanometer showed rhythmical alternations of the presence and absence of action currents Thus, when the instructions were to imagine performing an act involving a relatively brief muscular action (*e g* , throwing a ball), only a single brief series of long deflections was recorded, but when the subject was told to imagine throwing a ball three times, three distinct series of deflections were recorded, with rests between

Do the muscle fibers actually contract during imagination? Or is there merely physiological activity involving electrical changes without any actual shortening of the fibers? In investigating this problem a lever was arranged so that the flexion of the right arm could be magnified eightyfold and recorded photographically along with the action-current record. By means of this device, microscopic arm movements were found to occur when action currents were detected. These findings are in accord with other evidence which indicates that the occurrence of action currents always signifies the shortening of muscle fibers to some extent.

Is motor activity a necessary condition for imagination? The data reported above indicate that implicit muscular activity accompanies the imagining of overt motor acts. But they do not force us to the conclusion that a subject cannot imagine an act without engaging in microscopic movements (that is, that motor activity is necessary if imagination is to occur). Certain tests were made, in an attempt to investigate this fundamental question. The tests and their results were the following:

1. In one test the subject was instructed to cease imagining when he heard the second of the two signals. In a second test he was told to "relax any muscular tension present," at the second signal.

The photographic records were found to be identical in type in both cases. Ceasing to imagine seems to be the same process as relaxation.

2. The subject was given two tests, in both of which he was told to keep the arm completely relaxed at the first signal, and simultaneously to imagine bending the arm or lifting a weight. In one of these tests, the subject was told that in case it was impossible for him to do both, he was to imagine only. In the other test he was instructed that, if he was unable to relax and to imagine simultaneously, he was to keep all muscles relaxed.

Action currents were recorded under the first of these conditions but not under the second. This result suggests that the subject either imagines or relaxes. At any given time he cannot do both simultaneously.

Visual Imagination. Tests of visual imagery were also made with the electrodes placed near the eyeballs. The subject was instructed to imagine visually certain stipulated acts and objects. The records

indicated that the eye muscles were implicitly active during the acts of imagining but were relatively inactive before and after the period of imagining

Verbal Thinking. Positive results were likewise obtained when the electrodes were attached to the tongue or lip muscles and the subjects were instructed to imagine counting or telling a friend the date, or to think of abstract matters such as "eternity," "electrical resistance," "Ohm's law," etc Marked galvanometric deflections followed the first signal but ceased soon after the second signal In further tests, as in these, it was found that the deflections of the galvanometer during implicit speech corresponded with those recorded during audible speech

CONCLUSIONS

According to Jacobson, the results of his experiments lend support to the views that

1 Processes of imagining or thinking involve implicit motor activity

2 The motor activity associated with imagining and thinking is an essential condition for such processes, and is not a mere incidental accompaniment of their occurrence

3 The implicit activity involved in imagining a motor act is for the most part confined to the muscles which would be employed in the overt execution of the act, except in cases in which the act is described verbally or is imagined visually In such cases, implicit movements of the speech mechanisms or eye muscles occur

THE RELAXATION METHOD

It is worth noting that Dr Jacobson's interest in the motor theory of thinking derives largely from his advocacy of the so-called "relaxation method" of treating neurotics and other persons who exhibit excessive muscular tension. In the full "progressive relaxation" procedure described by Jacobson,[1] the patient learns to relax completely all the skeletal muscles of his body, by carefully planned and directed practice for 1 to 2 hr a day over a period of approximately 75 days He commonly begins by learning to relax the right arm, then the left arm, then the legs, then the trunk, neck, forehead, and so on Of especial importance is the fact that during the last 30 days of the program there is intensive practice in relaxing the eye muscles, and finally

[1] Jacobson, E *You Must Relax*, rev ed New York, McGraw-Hill 1942

the cheeks, jaws, lips, tongue, and the rest of the speech apparatus One of the general behavioral principles which can be advanced to justify the method is the fact that most "nervous" people are habitually in a condition of abnormally great muscular tension, largely because of their susceptibility to disturbing emotions of which such tension is a virtually invariable component If a nervous individual can learn voluntarily to relax all of his skeletal muscles more or less completely (there is always, in the healthy individual, the normal residual of muscular tonus), his "nervous" tension will be eliminated or greatly reduced Hence, the emotions themselves will be largely dissipated, at least so long as the relaxation can be maintained Similarly, if thinking typically requires—or is normally accompanied by—contractions in the muscles of the eyes or of the speech apparatus, it follows that if these muscles can be kept relaxed, thinking, at least in terms of visual imagery or subvocal speech, will become impossible This "elimination of thought," as Jacobson calls it, can be of great practical value for neurotics Much of their thinking is of such a nature that it readily induces distressing emotional reactions, and these in turn lead to a variety of bodily disturbances The method is widely used by psychiatrists and psychologists as a specific treatment for insomnia, a condition in which widespread muscular tension and disturbing thoughts are particularly obvious Jacobson reports it to be of great value for the alleviation of many other neurotic symptoms as well

II MAX'S EXPERIMENT ON THE "MOTOR THEORY OF CONSCIOUSNESS"[1]

INTRODUCTION

The investigations of Max have produced further evidence for an appraisal of the validity of the motor theory of thought and imagination

The question whether thinking necessarily involves motor responses is closely related to the broader problem of the physiological basis of consciousness in general Normally, thought and imagination are conscious processes, *i e*, they are activities of which the individual is aware If it were shown that there are action currents from muscles

[1] Adapted from Max, L W An Experimental Study of the Motor Theory of Consciousness III Action-current Responses in Deaf-Mutes during Sleep, Sensory Stimulation and Dreams *Journal of Comparative Psychology*, 1935, vol 19, pp 469–486

during all consciousness, even when the subject's experiences are too simple or too fragmentary to be termed "thoughts" or "imagination" the motor theory of thinking would receive strong support For if such relatively obscure phenomena were invariably accompanied by muscular movements, there would be every reason to believe that the much more vivid experiences which we term "acts of thought" or "imagination" would likewise involve muscular action

For similar reasons, further support would be given to the motor theory of thinking if it were shown that action currents tend to disappear in sleep (except when the individual is dreaming), to reappear as traces of consciousness reappear, and to become progressively more intense as conscious activities become more complex Moreover, if we may regard dreaming as thinking during sleep, then evidence of muscle-action currents while a subject is dreaming would be of considerable significance to the motor theory For these reasons, Max's experiments are highly pertinent to the specific problem treated in this chapter, even though their author terms them more generally studies of the "motor theory of consciousness" The first is reviewed below

PURPOSE

The aim of the experiment was to test the "motor theory of consciousness" (and therefore the motor theory of thinking) (1) by comparing action-current records obtained when a subject was awake and when he was asleep, (2) by comparing such records when a subject was dreaming and when his sleep was dreamless, and (3) by determining whether action currents occur following the application of stimuli during sleep

METHOD

Apparatus. The apparatus consisted of two extremely sensitive string galvanometers, each operating in conjunction with a set of vacuum-tube amplifiers The two amplifier-galvanometer circuits were independent, making it possible to record action currents from two different muscle groups simultaneously (In most cases one galvanometer was attached to the right arm and the other to the left arm) Photographic records were made of galvanometer deflections by means of an electrocardiograph camera The apparatus is represented in Fig 49

Subjects. The subjects were 19 deaf-mutes

Plan of the Experiment. Totally deaf subjects were used because the hands of the deaf are the seat of both their "oral" and written speech, and therefore the speech musculature of such subjects is far more accessible to experimental investigation than is the speech musculature (larynx and pharynx) of normal hearing subjects Max
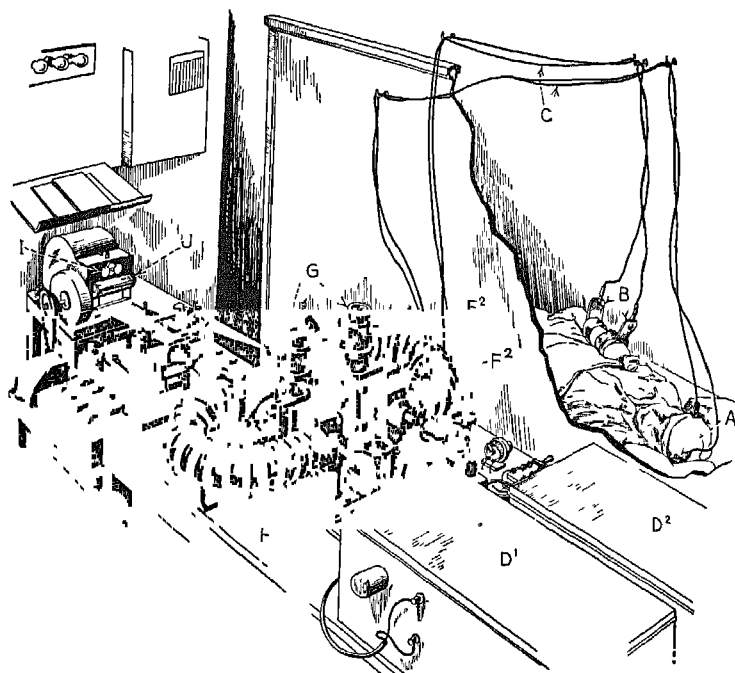
FIG 49 Max's Apparatus

This is a duplex apparatus which makes it possible to record action potentials from two parts of the body independently, or to record muscular action potentials and cerebral action potentials simultaneously, as in the case illustrated

A, brain electrodes, *B*, arm muscle electrodes, *C*, shielded wires connecting electrodes with amplifiers, D^1D^2, amplifiers, E^1E^2, string galvanometers, F^1F^2, the powerful horseshoe electromagnets of the galvanometers *G*, housings of the quartz filaments of the galvanometers, *H*, projection lamps, *I*, camera, *J*, narrow window through which shadows of vibrating quartz filaments are cast upon moving photographic film or paper (*Adapted from a drawing supplied by courtesy of Popular Science Monthly*)

thought that any records of implicit hand or arm movements obtained from deaf-mutes would be especially significant for the motor theory of consciousness Furthermore, records taken from the hands or arms of normal hearing subjects would provide an excellent control, since normal subjects do not think or speak with their hands.

Procedure. All the tests were made when the subject was asleep or preparing to go to sleep on a bed in the laboratory. Action-current records were obtained from the subject under both waking and sleeping conditions, and after the application of certain stimuli during sleep.

RESULTS

Waking versus Sleeping. For a time after the subject had been told to go to sleep, a considerable amount of action-current activity was recorded, but as the subject became more relaxed and comfortable, the action currents fell to a low level or disappeared entirely. Among the different subjects there were wide variations in the magnitude of initial action currents, but in all cases the currents showed a progressive decrease as sleep came on.

Quiet Sleep. In the records of 134 sleep periods for which no dreams were reported and during which there were no overt movements, there were 41 instances (31 per cent) in which action currents disappeared entirely during sleep. In 83 records (62 per cent) the action currents did not disappear altogether, but diminished progressively to a minimum of 0.9 to 0.1 microvolts. In 10 records (7 per cent) the response in quiet sleep was above 1 microvolt. In 69 per cent of the records, therefore, muscular activity was not entirely absent during dreamless sleep.

Dream Responses. In 33 cases, series of large action potentials (mean value, 3.67 microvolts) were recorded during sleep. After such action currents had been in progress a short time, but before they had disappeared, the subjects were awakened. In 30 of the 33 cases, subjects reported that they had just been dreaming, and in accordance with the experimenter's request, they proceeded directly to write out accounts of their dreams. In 6 cases, although introspective reports indicated that the dream content was primarily visual, the record showed definite action currents from the fingers. It was inferred, therefore, that verbalization processes may be involved in many "visual" dreams.

In one case, the experimenter pressed upon a subject's chest at a time when there had been no action-current activity for a considerable period. Following this stimulation, strong action currents were recorded from both arms. The subject was then awakened. He reported a dream of a barbecue party, at which he was excitedly arguing

with a fellow deaf-mute as to how best to insert the iron spit on which the meat was to be roasted The argument had been carried on by means of sign language

To see whether dreams ever occurred without action-current activity in the arm muscles, the subjects were awakened on 62 occasions during periods of electrical quiescence In 53 of these cases the subjects reported no dreams, but in 9 cases they claimed to have been dreaming However, these 9 cases were not definitely negative, for in 5 of them the content of the dream was primarily visual, and the seat of the motor activity may have been the eye muscles, which were not in the galvanometer circuit at the time

Duration of Dreams. The duration of the action-current activities in dreaming subjects is of interest in relation to the problem of the duration of dreams Many psychologists have held the view that even those dreams which seem especially long to the dreamer are in reality compressed into the brief period of a few seconds However, the periods of action-current activity which seemed to be definitely related to dream experiences were usually 2½ min or more in length

Response to Stimulation during Sleep. At various times, the experimenter presented auditory, tactual, and other stimuli to the subjects while they were asleep Care was taken not to use stimuli so intense as to awaken the subject Under these circumstances, action currents were recorded in 122 out of 187 cases Hence, even weak sensory stimulations normally aroused definite, though implicit, motor responses

Control Observations on Normal Hearing Subjects. During 33 tests on normal subjects during sleep no instance of action-current activity in either arms or legs was noted But when the subjects were awakened during these periods of electrical quiescence, 10 dreams were reported It is unfortunate that eye and vocal-organ records were not obtained for these subjects However, the absence of arm and finger activity in hearing subjects during dreams suggests that the manual-action currents recorded during the dreams of deaf-mutes are primarily linguistic in origin An attempt was made to find out whether similar action currents would be detected in the tongue and lip muscles of normal hearing subjects during dreams However the discomfort induced by the apparatus was so great that only four subjects were able to fall asleep under these conditions, and in those four cases, even dur-

ing dreamless sleep, the minimal response registered by the tongue was 6 microvolts, compared with an average of 1 microvolt from the arms of the same subjects

SUMMARY

Max summarizes the results of his experiment as follows

1 The transition from the waking to the sleeping state was accompanied by a progressive diminution of action-current responses from the peripheral musculature of both deaf and hearing subjects

2 In deaf subjects, sleep resulted in the complete absence of action-current activity in only a small proportion of the cases In the majority of cases, the action currents persisted but at a markedly diminished intensity

3 The onset of dreams in deaf subjects could be detected in most cases by the appearance of large action-current responses in the arm and finger muscles Such currents were unaccompanied by overt muscular movements and were distinguishable from those due to motility changes (restless movements of hands, etc) Dream responses were sometimes induced by special sensory stimulation and were of longer duration than the few seconds frequently ascribed to dreams

4 External stimulation introduced during sleep frequently evoked action currents in the peripheral musculature of the deaf

Max points out that several questions call for further investigation Among them are the following What is the significance of the slight amount of residual muscular activity recorded during dreamless sleep? Is the quantity of residual action-current activity an index of depth of sleep? Is there a relation between depth of sleep and the latent period of action-current response to sensory stimulation? How much of the motor response observed originates in speech mechanisms, and how much in the musculature generally? Is the demonstrated motor activity an essential concomitant or a mere by-product of conscious experience? Does the magnitude of the action-current response vary with the intensity of consciousness?

III FURTHER STUDIES OF THE "MOTOR THEORY OF CONSCIOUSNESS"[1]

A second series of experiments was later conducted in which Max obtained action-current records from the hands of deaf-mute subjects

[1] Adapted from Max, L W Experimental Study of the Motor Theory of Conscious

during the transition from sleep to the waking state, during periods when the subjects reported kinesthetic imagery, and during thinking As before, control tests were run with normal subjects The apparatus and general method were identical with those of his earlier study The results of this second investigation may be summarized briefly as follows

Awakening. When a sleeping deaf-mute subject was suddenly awakened by the experimenter, there was always a violent onset of action-current activity Much of this activity could be attributed to the overt limb movements connected with waking But in 20 cases in which no visible movements occurred, there was, nevertheless, a steady increase in the amplitude of action-current response as the subject gradually awakened In all subjects, a maximum of electrical response was reached soon after awakening Then, as the subject relaxed, preparatory to the experimenter's presentation of a thought problem, the amount of electrical activity diminished

Kinesthetic Imagery. The subjects were told to imagine such acts as holding a wriggling snake behind the head, holding a squirming fish in the hands, telegraphing an S O S signal, typewriting, etc Under these circumstances, the electrical records showed that the subjective experience of a kinesthetic image as reported by the subjects was usually accompanied by actual contractions of the muscles which would be active in the performance of the acts imagined In fact, the muscle contractions were sometimes large enough to be detected without any amplification It was also found that below a certain microvoltage, the magnitude of which varied with different individuals, the subjects did not kinesthetically perceive muscular contractions, which, although feeble, were definitely present

Abstract Thinking. Abstract thought problems, such as adding multiplying, and dividing mentally, reading, and selecting appropriate sentences in multiple-choice tests, etc , were given to the subjects During the solution of these problems, action currents of hand and finger muscles occurred in 84 per cent of the cases with 18 deaf subjects, as compared with only 31 per cent of the cases with 16 hearing subjects (Such action currents as were recorded from the finger muscles of hearing subjects may be at least partially explained by the

ness, IV Action-current Responses in the Deaf during Awakening, Kinaesthetic Imagery and Abstract Thinking *Journal of Comparative Psychology*, 1937, vol 24, pp 301–344

fact that many normal individuals perform arithmetic calculations with the aid of the fingers) The two groups differed also with respect to the average amplitude of reponse, which was 3 4 microvolts for the deaf and only 0 8 microvolt for the hearing subjects But when the subjects were instructed to imagine that they were performing tasks which would involve the use of the arm muscles, the percentage of positive arm responses from deaf and hearing subjects was substantially the same *Hence*, during thought problems the arms and hands of the deaf yielded larger and far more frequent responses than did the arms and hands of the normal subjects

Discussion

In this chapter we have described several investigations upon the motor theory of thinking and of consciousness The results of the experiments both of Jacobson and of Max lend substantial support to the motor theory

Jacobson found that implicit motor activity occurred during thinking and imagining He found, moreover, that motor activity was most intense in the limb muscles which would be activated if the imagined act were actually being executed or, in the case of visual imagery and verbal thinking, in the eyes and speech mechanisms, respectively On the basis of these findings, Jacobson concluded that motor activity is an essential condition for thinking

In his investigation of the motor theory of consciousness, Max discovered that dreamless sleep was normally accompanied by a cessation or a diminution of muscle-action currents, but that in dreaming an increase in the currents generally occurred Like Jacobson, he found that imagining the performance of an action produced responses in the body parts which would be involved in the overt commission of the act Max also found that when deaf-mute subjects were dreaming (which may be regarded as thinking during sleep), or were solving abstract problems in the waking state, action currents were usually recorded from the arm muscles, whereas in normal hearing subjects very little activity in this part of the body was detected According to the motor theory of thinking, the thinking of deaf-mutes should often involve activity in the manual organs which they use in their "sign language," just as the thinking of hearing subjects should often involve activity in the vocal mechanisms The results of Max's investigations, therefore, are in accord with the postulates of the motor theory

However, it cannot be inferred from these results that the motor theory of thinking is to be regarded as fully substantiated. Although the above data constitute strong *supporting* evidence, they are not *conclusive* evidence. The data show that muscular activity is usually, if not always, correlated with thinking. Moreover, to many psychologists Jacobson's results prove that motor response is an essential condition for thought. However, it remains to be demonstrated that the motor response is the most essential process of thought itself.

CHAPTER XXV

PROJECTION AND THE THEMATIC APPERCEPTION TEST

Introduction

Projection is one of the most common and one of the most important ways in which human beings perceive and think about objects in the external environment. According to Symonds[1] it may be defined as "the reference of impulses, thoughts, feelings and wishes originating in the person himself to persons and objects in the outside world." The process is usually (some say always) unconscious, in the sense that the individual does not know that he is coloring and perhaps distorting his apprehension of external objects and people by imbuing them with his own characteristics.

Most accounts of projection emphasize the point that we typically tend to project our undesirable traits.[2] Thus a low-grade workman may blame his tools for his poor work, instead of himself, which means that he projects his own inefficiency into the instruments he uses and perceives them rather than his own clumsiness as at fault. An individual who is a habitual cheater may console himself with the reflection that everyone cheats anyway. Bernard Shaw is said to have remarked that the chief punishment of a liar is that he cannot believe others. The paranoiac projects his feelings of hatred and suspicion of other people and develops delusions of persecution, that is, convictions to the

[1] Symonds, P. M. *The Dynamics of Human Adjustment*, p. 296. New York, Appleton, 1946.

[2] According to some definitions, projection always is defensive and involves the ascription of only undesirable traits to objects and to other persons. Thus Healy *et al.* define projection in psychoanalytic terms as a "defensive process under the sway of the pleasure principle whereby the ego thrusts forth on the external world wishes and ideas which, if allowed to penetrate into consciousness, would be painful to the ego." (Healy, W., A. F. Bronner, and A. M. Bowers. *The Structure and Meaning of Psychoanalysis*. New York, Knopf, 1930.) To the reviewers, such an interpretation seems unduly narrow. Indeed, Freud himself came to use projection in the broader sense in which it will be employed in this chapter. (See *Totem and Taboo* in *The Basic Writings of Sigmund Freud*. New York, Modern Lib., 1938.)

effect that other persons hate him and are trying to do him harm This projection of undesirable traits into the environment is typically a kind of defense reaction, in that we thereby protect ourselves from having to recognize our own faults—or find excuses for our own shortcomings—by perceiving the very same defects in other things and people

However, it also is possible to project desirable characteristics, or for that matter, traits which are not commonly judged as being either good or bad in any definite sense of the words Thus children, and individuals from primitive cultures, tend to project many of their own traits into inanimate objects, and animistically endow hills, streams, the sun, the wind, and the rain with characteristics which only living organisms like themselves possess Similarly, children and many adults also—project their own traits into animals and perceive and think about animals anthropomorphically, that is, as feeling, thinking, and desiring in an altogether human fashion Poets and novelists frequently project their own emotions and conflicts into their characters and create individuals whose traits and experiences reflect- and thus often strikingly reveal-- the authors' own feelings and desires

Projection was first described by Sigmund Freud, the founder of psychoanalysis, in 1894 [1] It is very unlikely that Freud was the first observer of human nature to realize that the tendency to interpret external objects in terms of ourselves is a conspicuous and ubiquitous human characteristic However, he was the first person in the field of psychology to give the process a name, to define it and to make clear its importance

During the past 50 years, psychologists and psychiatrists have become increasingly aware of the significance of the projection process They have come to realize that this process is typical of much of the perceiving and thinking of normal individuals, and that it is also responsible for many of the gross misinterpretations of the external world which characterize serious mental disorders

Furthermore, in recent years psychologists and others have developed a number of different projective tests, in which the test situation and the instructions to the subject are so designed that the lat-

[1] Freud, S The Justification for Detaching from Neurasthenia a Particular Syndrome The Anxiety Neurosis *Collected Papers*, International Psychoanalytical Library, No 7, Vol 1, pp 76–106 London Hogarth 1924.

ter's responses tend to be projections of his feelings, attitudes, thoughts, and desires The administration and interpretation of these projective tests have become the most widely used method for discovering certain more or less hidden aspects of a subject's personality and for obtaining a rapid appraisal of his personality as a whole

The first important projective test, and the one still in widest use, is the Rorschach This test is described in most textbooks of general psychology It may suffice here to say that it consists of a standard series of 10 different ink blots These are shown to the subject, one at a time, and for each the subject is asked to state what he sees, what it might be, what it makes him think of Since each ink blot is an essentially meaningless figure, different people perceive it very differently and are led to think of very different things when they observe it Thus projective reactions are very apt to occur Examples of such reactions are given by Lindner,[1] who finds that to see "eyes looking at me" in either of two of the Rorschach cards is a typical paranoid[2] reaction, and that to interpret the "human figures" which many see in a certain ink blot as "puppets or marionettes" is characteristic of schizophrenics[3] who feel themselves directed, influenced, and manipulated by other persons who are hostile to them In this way the Rorschach test may reveal aspects of a subject's feeling and thinking of which the subject is quite unaware, and which could be discovered only with difficulty, if at all, by any sort of direct questioning procedure [4]

Another widely used projective test, and the one with which the present chapter is primarily concerned is the Thematic Apperception Test (the TAT) devised by Morgan and Murray and first mentioned

[1] Lindner, R M Some Significant Rorschach Responses *Journal of Criminal Psychopathology*, 1944, vol 5, pp 775–778

[2] As we have said, a paranoiac perceives in other persons the malice and hatred that actually are within himself

[3] Schizophrenia, like paranoia, is one of the most serious types of psychosis, *i e*, of severe mental disorder

[4] Actually, the content of a subject's Rorschach responses, *e g*, whether a particular ink blot suggests a human being to him and, if so, what he imagines the latter to be doing, is only one of his reaction characteristics which is regarded as important Even more significant are certain general aspects of his responses, such as the total number of things the ink blots suggest to him, whether his response is determined more by the ink blot as a whole or by some detail of it, how he is affected by color (in those cards in which it appears), and so on.

in the literature in 1935[1] This test consists of a standard series of 20 pictures, each of which depicts some event, usually of a dramatic nature[2] For example, in one picture a woman is clutching the shoulders of a man whose face and shoulders are averted as if he were trying to pull away from her, in another a boy is huddled on the floor against a couch, with his head bowed on his right arm and a revolver on the

FIG 50 One of the TAT Pictures (*Reproduced by permission of the Harvard University Press*)

floor beside him The subject is shown the pictures one at a time and is asked to make up a story about each of them The objective characteristics of the picture, of course, set some limits to his narrative. For example, any story about the last-mentioned picture normally would include reference to the boy and to the weapon However

[1] Morgan, C D, and H A Murray A Method for Investigating Phantasies The Thematic Apperception Test *Archives of Neurology and Psychiatry*, Chicago, 1935, vol 34, pp 289–306

[2] One of these pictures is reproduced in Fig 50

within these limits, a very wide range of interpretations is possible Thus, in the above picture, the boy may be viewed as struggling against the temptation to kill someone, as having done so already, as having witnessed a murder the perpetrator of which has escaped leaving his weapon behind him, etc His emotional state may be characterized as one of remorse and guilt, or terror, or anger If the subject conceives that it is anger, he may describe the object of the boy's hostility as being his father, his mother, a brother or sister, a girl, a male acquaintance, etc Naturally further details of the story, such as the events which led to the tragic situation and what the final outcome will be, may vary endlessly

Since the stimulus situation, and the experimenter's instructions, permit the subject to read into the picture almost anything he happens to think of,[1] opportunity for projection on a considerable scale is afforded The subject can invent almost any story he pleases The narrative which he does invent is regarded as being expressive of his own personal feelings, motives, and problems Thus, for example, if a subject's story is analyzed for indications of aggressiveness, it is often found that the degree of aggressiveness which is suggested by this analysis is corroborated by evidence obtained through clinical and biographical study of the subject Hence the subject appears often to project his attitudes into his stories and to reveal in this way significant personal traits of which he himself may be unaware (There are several other important types of projection tests Discussion of these, however, is beyond the scope of this chapter)

The discussion so far probably has given the impression that (1) projection is a type of reaction the existence of which is completely substantiated, and that (2) the so-called "projective tests," especially the TAT, have been proved to yield projective responses capable of a clear and direct interpretation According to certain psychological viewpoints, this impression might be regarded as entirely correct However, experiments which actually attempt to produce and study the phenomenon of projection have been very few in number Most psychologists, although they may be inclined to accept the concept of

[1] It is instructive to compare the wide latitude of responses permitted in the TAT with the restriction of reactions characteristic of most intelligence-test questions, *e g* , in such a question as, "Which of the following words is the opposite of loyal enemy, treacherous, thief, coward, jealous?"

projection on the basis of general psychological theory and of clinical evidence from individual case studies, would welcome *experimental demonstrations* of its occurrence In addition, psychologists who use projective tests as one of their clinical procedures would appreciate *actual proof* that a subject's feelings and attitudes do influence his test responses, even though they may regard the existence of such a relationship as highly probable Among the very few investigations in which an experimental control of projection has been attempted are the studies of Bellak which constitute the principal basis of this chapter

BELLAK'S EXPERIMENTS ON PROJECTION AND THE THEMATIC APPERCEPTION TEST[1]

PURPOSE GENERAL PLAN

The aims of Bellak's experiments were to "test the existence of the hypothetical process of projection," and to find out whether projection actually occurs in responses to the TAT

The general plan of the experiments was to obtain a subject's responses (*i e* , his stories) to a number of TAT pictures under normal conditions, then to obtain his responses to an equivalent series of TAT pictures after an emotional attitude of resentfulness and hostility (in one experiment, of depression) had been aroused in him If people do tend to project their emotions, and if the TAT provides an appropriate situation for such projection, the subject's responses after the arousal of the emotion should contain more indications of aggressiveness (or of depression) than they did before the emotion was present

EXPERIMENT I

Subjects. The subjects of Bellak's first experiment were seven Harvard University students, all members of the Reserve Officers' Training Corps They were met by the experimenter in connection with a personality examination, and were entirely ignorant of the purpose of the experiment

Material. The material consisted of 10 of the 20 TAT pictures divided into 2 sets of 5 pictures each The pictures selected were as

[1] Adapted from Bellak, L The Concept of Projection, an Experimental Investigation and Study of the Concept *Psychiatry*, 1944, vol 7, pp 353–370

follows:

Set A
- (*a*) A surgical operation with a young man in the foreground
- (*b*) A man on a couch, with another man bent over him
- (*c*) Cowboys at rest
- (*d*) A man with raised fist
- (*e*) Two boys standing in an archway

Set B
- (1) A mother and son
- (2) A boy on a couch with a revolver on the floor (the picture previously described)
- (3) A nude man and a nude woman faced by a clothed woman holding a baby
- (4) An older, gray-haired man facing a younger man
- (5) A man gripped from behind by several disembodied hands

Three subjects were given Set A first, then Set B; the remaining four subjects received Set B first and Set A second.

Method. The method was as follows. Each subject was interviewed individually, in a room which, in order to minimize distractions, contained little more than a couch, a chair, and a table lamp. A microphone concealed in the lamp transmitted the subject's oral story, in some sessions to a stenographer, in others to a recording device, each located on another floor of the building. During the interview, the subject was asked to lie down on the couch; the experimenter sat behind him.

The subject received these standardized instructions:

> This is an opportunity for free imagination. I want you to make up a story. Tell me what has led up to the situation shown in the picture, describe what the characters are feeling, and tell me what the outcome will be. Speak your thoughts out loud as they come to your mind. Use your imagination and make up anything you please.

After these instructions, the subject was given the first picture. As soon as he had completed his story about it, he returned the picture, was given the next one, and so on. If a subject asked whether he should stop or should continue his narrative, he was told that this was always for him to decide, and that whenever he felt he had said all he wanted to say he was simply to hand back the picture. The experimenter made no comments whatever on the subject's stories until the response to the fifth picture had been made.

After each subject's fifth story, however, and also after his sixth, seventh, eighth, and ninth stories, the experimenter criticized his production sharply, using a caustic tone of voice The criticisms, which were identical for all subjects, were as follows

[After the fifth story], "These stories are about the worst I ever heard They are illogical and unstructured Could you try to get some better ones?" [After the sixth story], "There are still no ideas in it, no life, no nothing Could you try some more?" [After the seventh story], "This is some of the damnedest stuff I have ever got Try this one" [After the eighth story], "You are pretty hopeless See what you can do with this one" [And after the ninth story], "Well, this is your last chance to show if you have anything in you Go ahead"

After a subject had responded to each of the 10 pictures, the session was ended His stories, which had been recorded either in shorthand or mechanically, were now typewritten Next they were carefully analyzed by the experimenter and also by two other psychologists who were unacquainted with the aims of the investigation The analysis was for the express purpose of detecting evidence of aggressiveness in the subject's stories, and was accomplished by counting every word of an aggressive nature in them It was found that the three counts of aggressive words made independently by the three judges differed only slightly, hence the figures presented under "Results" in Table 1 are the averages of the three counts.[1]

In order to illustrate the difference between stories containing a relatively small and a relatively large number of aggressive words, two narratives given by two different subjects in response to picture 2 in Set B are reproduced below[2] In each story the words scored as aggressive are italicized The aggressiveness scores for the two stories are 2 and 8 words, respectively

(1) I'd say that he was a boy, probably in high school or perhaps just in high school, that, ah he's been disappointed by his latest report card and he had received a *scolding* from his family a little bit disappointed but possibly more disappointed in the fact that he was being *punished* by getting a bad mark very unhappy at the time and, ah and he probably feels at the moment that life

[1] In addition, each judge rated each story, considered as a whole, on a five point scale for aggressiveness The results obtained by this method were judged to agree closely with those obtained by the method of counting aggressive words and are not presented by Bellak in his published article

[2] These two stories, not presented in the published article, were kindly furnished by Dr L Bellak.

is pretty dreary and bitter and he doesn't have much to look forward to . thoroughly unhappy but seems to me to be rather passing He will probably get over it and he will go back to school, maybe work a little bit harder and probably next time he will get a little better marks

(2) Well, just like this young fellow, this is his *gun* down there I will tell it like this This young fellow has led an unhappy life His father and mother have been *mean* to him He's led an unhappy home life He is about ten years old He comes home from school and things have been going badly He comes home and his father is *threatening* his mother He sees his father's *gun* lying there and rushes over and gets his father's *gun* and he *kills* him, *kills* them both, and after he's done that and sees what he's done and that he has *killed* them he leans over and cries and then he calls up the police and they take him away The next one I'll make up a happy story

Results Table I gives the results of the experiment.

TABLE I

The Total Number of Aggressive Words Given by Each Subject, for Each Set of Pictures under the Two Conditions, without Criticism and with Criticism

Set and condition	Number of aggressive words				
	Individual subjects				Total
	Ma	Fr	Am		
Set A, without criticism	0	3	2		5
Set B, with criticism	12	11	9		32
	Mc	Ha	Go	De	
Set B, without criticism	8	4	3	4	19
Set A, with criticism	6	1	2	4	13

The results show that the group which had Set A without criticism and Set B with criticism gave more than six times as many aggressive responses (words) to Set B than they did to Set A However, the group which had Set B without criticism and Set A with criticism made somewhat fewer aggressive responses to the latter set In all probability, the reason for these apparently inconsistent results is that the pictures of Set B were intrinsically more likely to elicit stories containing an aggressive content than were those of Set A Hence, for the second group, even the experimenter's criticisms could not produce more aggressive responses for Set A

However, if one compares the number of aggressive words given for each set with and without criticism, the effects of the criticism become more evident Set A without criticism yielded a total of 5 aggressive

words, an average of 1 67 per subject, but with criticism it yielded 13, an average of 3 25 Similarly, Set B evoked 19 aggressive words without criticism (average, 4 75), but with criticism it elicited 32 (average, 10 67)

Discussion. The interpretation of these results would appear to be as follows The subjects usually gave evidence of being disturbed by the criticisms, even though some of them denied that they were much concerned One subject said he felt completely discouraged, another, who stuttered, had more difficulty in speaking when criticized A few subjects exhibited hand tremors and paling or blushing of the face Two subjects expressed their resentment openly by blaming the poor quality of the pictures, one blamed the experimenter for the vagueness of his instructions The subjects, therefore, tended to become disturbed, angry, and resentful They could not express their resentment fully and directly, since the experimenter was to them an "authoritative person" Hence they tended to express it, at least in some degree, by projection That is, after having been subjected to criticism, they tended to invent stories involving more aggression on the part of the characters in them [1]

However, the results also show that the nature of a picture, as well as the feelings and attitudes of the subject, influences the story which a subject devises, witness the considerably greater number of aggressive responses elicited by Set B than by Set A under normal conditions This finding suggested to Bellak a second experiment, in which the two sets of pictures would be equated beforehand for the number of aggressive reactions which they normally produce

EXPERIMENT II

Purpose. The aim of Bellak's second experiment was to determine the effect of criticism by the experimenter upon a subject's responses to TAT pictures, when the pictures used under the "without criticism" and the "with criticism" conditions are equated for the number of aggressive responses which they evoke under normal circumstances

[1] In Table I this conclusion is directly confirmed only for subjects Ma, Fr, and Am, who had Set A without and Set B with criticism However, additional evidence for the conclusion is derived from a comparison which Bellak made between the stories told for Set B with criticism, in the present experiment, and the stories told for the same pictures by 25 individuals who took the entire test for another purpose and under normal conditions (*i e*, without criticism) The stories obtained in the present experiment contained on the average almost three times as many aggressive words

Subjects. The subjects were 10 Harvard University students, who were sent to the laboratory by the Student Employment Office and who were paid for their services None of them had studied psychology, and all were ignorant of the purpose of the experiment

Material. The material consisted of two sets of five TAT pictures each The pictures in the two sets (C and D) were matched for the degree to which they suggested aggressive stories by counting the number of aggressive responses (words) made to them by about 50 subjects in other investigations These subjects had taken the test under normal conditions, that is, the experimenter had listened to and recorded their stories with no comments of any sort, critical or otherwise

The two sets consisted of the following pictures

Set C
- (*a*) A man with upraised arm and open mouth
- (*b*) A rural scene
- (*c*) A man gripped from behind (also used in Experiment I as picture 5 of Set B)
- (*d*) An operation (formerly picture *a* of Set A)
- (*e*) A man shaking his fist

Set D
- (1) A young woman clutching a young man
- (2) A boy on a couch with a revolver on the floor (formerly picture 2 of Set B)
- (3) A man's silhouette against a window
- (4) Two boys standing in an archway (formerly picture *e* of Set A)
- (5) A gray-haired man facing a younger man (formerly picture 4 of Set B)

Five subjects were given Set C first, then Set D For the remaining five subjects the order in which the sets were given was reversed

Method. The method was exactly the same as in Experiment I, except for some minor changes in the precise wording of the instructions to the subjects The criticisms were identical with those of Experiment I, and the analysis of the stories was made in the same way as it was in the first experiment

Results. Bellak does not give the results of his second experiment in the detailed fashion that he did for his first experiment However, he reports that the average number of aggressive words per subject before criticism was 12 6, and after criticism 23 7, giving a statistically reliable difference of 11.1 words.[1]

[1] For a definition of statistical reliability of a difference, see Chap I p 9

Although data are not presented for each set of pictures separately, it is stated that the two sets proved to be about equal in their capacity to evoke aggressive responses after criticism These results are interpreted as providing further evidence for the occurrence of projection in TAT responses. The reasons for this interpretation are identical with those already presented in connection with the discussion of Experiment I.

EXPERIMENT III[1]

Purpose and General Procedure. Bellak continued his study of projection and the TAT with a third experiment in which he used post-hypnotic instructions or suggestions,[2] instead of criticism of his subjects in the normal waking state, to induce a mood of anger and hostility It is well known that feelings and attitudes of virtually any desired kind can be induced readily by an expert hypnotist in a good hypnotic subject Bellak's plan was to have his subjects give stories as responses to TAT pictures, first under a control condition (*i e*, under normal circumstances), and second under the experimental condition, which in this investigation was a condition of hypnotically induced anger

Subjects. This experiment was performed at St Elizabeth's Hospital, in Washington, D C The subjects consisted of a group of five Navy corpsmen assigned to the hospital as male nurses for psychiatric patients, and a group of five male theological seminary students, who were being given clinical training and doing nursing duty at the hospital The motive of the subjects for volunteering was primarily an expressed curiosity about hypnosis, as well as a desire to find out whether they personally could be hypnotized and to learn how it felt to be hypnotized All of them were quite unaware of the purpose of the experiment However, they were fully informed of its purpose and results after their work in it had been completed The 10 men

[1] Adapted from portions of Dr L Bellak's doctoral dissertation (as yet unpublished) at Harvard University

[2] In posthypnotic instruction, or posthypnotic suggestion, a subject is directed while in the hypnotic condition to respond in certain prescribed ways at some specified time after he has been awakened from that condition Usually the subject also is told that he will be amnesic for the instructions, that is, that he will not remember having received them Hence a good hypnotic subject, given the posthypnotic suggestion that he will take a drink of water at exactly 3 P M, will get the water at the stipulated time when he is no longer in the hypnotic state, but will not have any knowledge of why he performs the act

used as subjects were chosen from among a total of 50 volunteers as being in the experimenter's judgment those most capable of deep hypnosis and most able or willing to comply in full with the posthypnotic instructions

Material. The material was the same two sets of TAT cards that had been used in Experiment II, except for the substitution of another TAT card for one of the cards of Set D

Method. The control condition was given first for all the subjects In this condition the subject was presented in succession with the five pictures of one set, in the same manner and with essentially the same instructions as had been used in Experiments I and II for the first five pictures before criticism The five corpsmen received Set D under this condition, the five theological seminary students received Set C

Each subject was then hypnotized deeply and was given the following posthypnotic instructions

> After you have awakened you will feel tremendously angry inside, you will be boiling and awfully angry without realizing that you are angry and without remembering that you are angry because I told you to be
>
> After you awaken you will not remember anything that went on in hypnosis, but you will be angry inside, without realizing it
>
> You will tell stories about five pictures After you have finished the fifth story about the fifth picture, you will suddenly say that you were awfully angry inside You will suddenly remember everything that went on in hypnosis, and at the same time your anger will cease and you will feel very happy, relaxed, and comfortable [1]

It should be noted that the subjects were told to be angry, yet at the same time were told to be unaware of the emotion The reason for this stipulation was that Bellak thought that the clinical significance of responses to the TAT would be particularly well demonstrated if projection of feelings of which the subject was unaware could be produced In order to find out whether the posthypnotic instructions were being followed, the subjects were closely observed and carefully questioned before they were given the first picture of the experimental

[1] The last sentence of the instructions is typical of the way in which posthypnotic instructions usually end Its primary aim was to make certain that none of the subjects would suffer any harm from the experience—for example, that none would be left with any permanent amnesia for the events of the hypnotic condition, or would be subject to any bewilderment, confusion, and the like Such precautions are necessary, especially in view of the common belief that being hypnotized may constitute an injurious experience

set, and after they had finished their stories for the third and fifth pictures of this set. The records of any individual who did not comply fully with all the instructions were discarded, and not considered in the results. As one evidence of the success of the posthypnotic suggestions with the subjects used, Bellak notes that frequently he observed in them such evidences of anger as fast breathing, a flushed face, and strong pencil pressure (while writing their stories).

The five stories given in the experimental condition are designated as "stories with hypnosis," since the subjects produced them under the influence of the posthypnotic instructions. These stories were

TABLE II

The Total Number of Aggressive Words Given by Each Subject, for Each Set of Pictures, under the Two Conditions, Normal and with Hypnosis (Control and Experimental)

Subjects	Number of aggressive words					
	Individual subjects					Average
Corpsmen						
Set D, normal condition	20	17	21	21	17	19.2
Set C, with hypnosis	37	41	60	56	39	46.6
Seminary students						
Set C, normal condition	3	22	19	9	12	13.4
Set D, with hypnosis	42	49	32	21	33	35.4

not given orally by the subjects, as was the case in the control condition (and in Experiments I and II), but instead were *written* by them. This variation in the procedure was introduced because it was felt that the subjects would be more apt to comply fully with the instructions if they could work by themselves without having to face, and talk to, the experimenter.

All of the stories were carefully analyzed, as in the previous experiments, in order to determine the number of aggressive words which they contained. In the present investigation the analyses were made by a doctor stationed at the hospital, who was unfamiliar with the nature of the experiment.

Results. The results of Experiment III are given in Table II.

Discussion. The results show clearly that in the experimental condition, under the posthypnotic instructions to be "tremendously angry" though without awareness of such an emotion, the subjects told

stories which contained a much larger number of aggressive words than did their stories told in the control condition. This result was obtained for both groups of subjects and for both sets of pictures, and is reported by Bellak to be statistically reliable. Comparison with the results of Experiment II (in which virtually the same sets of pictures were used) shows that the average number of aggressive words under the control condition was approximately the same for the seminary students in the present study and for the 10 subjects in the former experiment, the averages being 13 4 and 12 6, respectively However, the average number of such words given by the corpsmen in the control condition was considerably greater than the above figures This result suggests to Bellak that the personalities of the corpsmen tended to be more aggressive than those of either the Harvard University students of Experiment II or the theological seminary students of the present investigation Also, under the hypnotic condition, both groups of subjects in the present experiment gave a larger average number of aggressive words than had been obtained in either of the earlier studies, with any group or any set of pictures In explanation of this difference, it is very probable that the posthypnotic instructions were more effective for inducing anger than were the personal criticisms used in Experiments I and II It also is conceivable that the instruction to remain unaware of the anger resulted in a more extensive projection of the emotional attitude

Experiment IV

Bellak also performed a fourth experiment[1] which will be reported briefly The subjects were 12 of his acquaintances Posthypnotic suggestions again formed the basis for the experimental condition In this investigation the subjects first reacted to five TAT pictures in a normal state The procedure was identical with that used in the control condition in the first three experiments except that the subjects *wrote* their stories instead of relating them orally The subjects were then hypnotized (as in Experiment III) and were given posthypnotic instructions calculated to arouse *depressed* feelings Specifically they were told "After you have awakened, you will feel awfully unhappy and depressed inside, without being aware of it You will feel as if somebody very dear to you were seriously ill, or had died"

[1] Bellak's fourth experiment also is an unpublished part of his doctoral dissertation

Otherwise the instructions were essentially the same as in Experiment II As before, the subjects, upon awakening from the hypnotic condition, were presented with five TAT pictures and wrote a story about each of them

The principal result was that a much greater number of depressed words and phrases was given under the hypnotic condition than under the normal one The average number of such items, for all five pictures taken together, was 10 4 for the 12 subjects in the normal state and 26 2 for the subjects in the hypnotic condition The difference of 15 8 is statistically reliable Furthermore, every one of the 12 subjects gave more depressed words and phrases under the hypnotic state than under the control condition In some cases the differences were striking For example, two subjects gave a total of 3 and 4 words, respectively, in the normal state, but gave totals of 44 and 33, respectively, while under the influence of the posthypnotic instructions [1] [2]

Discussion

In this chapter, projection has been dealt with from two viewpoints (1) as a way of perceiving and thinking about objects and people in the external environment, and (2) as a kind of reaction which projective tests—among them the TAT—are believed to induce in significant fashion and degree

The results of the experiments of Bellak support the conclusion, favored by clinical evidence and psychological theory, that human beings do project their "impulses, thoughts, feelings and wishes" into external objects For in these studies the subjects projected the resentment and aggression resulting from personal criticism, and anger or depression hypnotically induced, into a selected series of pictures about which the subject could invent any stories he pleased

As we have said, projection is both a way of perceiving external objects and a way of thinking about them According to Bellak, the projective process may be regarded as arising from a readiness, a set,

[1] However, it must be noted that no attempt was made to equate the pictures used in the two conditions

[2] Bellak also reports the results obtained by hypnotizing a female nurse and giving her posthypnotic instructions to feel "extremely happy" This subject, in response to TAT pictures, "gave stories full of happiness to the extent that even a horse in one of the pictures was said to have a happy expression"

to react in accordance with some feeling or attitude [1] A vindictive person tends to perceive most other people as malicious and hostile, and in his thinking about them he is apt to imagine them as acting in accordance with those characteristics These reactions are due to his own attitudes of hatred and hostility, which keep him continually ready or set to make such interpretations The tendency often is protective or defensive, in that it may help to prevent an individual from recognizing his own undesirable traits and thus aid him in maintaining his self-esteem

However, as Bellak demonstrated in his first experiment, as a rule, projection does not occur without reference to the objective nature of the stimulus An individual who tends to project his hostility will not do so in equal degree into all other persons Some of the people he meets may display a friendliness so patent that even he will find it difficult to perceive them as hostile (though if he is an actual paranoiac he may construe their friendliness as designed to hide their evil intentions) But if the behavior of another person is ambiguous, in the sense that it does not exhibit clear indications of either hostility or friendliness, then the individual who is characterized by many animosities and who habitually projects his hatreds is very likely to regard him as an enemy [2]

Bellak's results also indicate that the TAT really is a projective test in that the subjects tended to devise stories which contained more aggressive (or depressed) words after feelings of resentment (or sadness) had been aroused in them Hence Bellak's data provide important experimental evidence for the opinion prevalent among psychologists who use the test, that the TAT pictures are well designed for the purpose of eliciting projective responses [3]

It is worth reiterating that the attitudes, etc , which the subject projects may be only partly known, or at times quite unknown to him Thus a subject in his various stories may repeatedly introduce the theme of a father's mistreatment of his son and the consequent resentment and antagonism of the latter Even if the subject asserts that his own attitude toward his father is one of affection and gratitude,

[1] For a definition of "attitude" see Chap XXII

[2] For a brief discussion of the effects of attitudes on the perception of objects of different degrees of clarity or ambiguity, see Chap XXII

[3] This statement does not in any sense imply that the TAT is the only test which elicits significant projective reactions

the clinician would be likely to conclude that the subject's narratives offered strong evidence to the contrary, or at least evidence of ambivalence[1] and conflict If this viewpoint is correct, then a principal value of the TAT is to reveal motives and attitudes of which the subject is ignorant (often through repression[2] and rationalization), or which he refuses to admit are his characteristics As we have said, another value of this test (and of many other projective tests as well) is that the experimenter, through his analytic study of the subject's responses, may obtain clues to the probable personality traits of the subject more quickly than can be accomplished by any other available means

Finally, one might note a rather obvious point, namely, that projection typically is a fault, a deficiency, rather than an asset, in that it tends to produce misinterpretations of external objects and people It is apparent that this process may corrupt in some degree the perceiving and thinking of almost everyone even if it is desirable rather than undesirable traits that are projected And in some gravely disturbed neurotics and psychotics it acquires a magnitude, grossness, and persistence that seriously impair their adjustment to their environment, especially their social adjustments to other people

[1] "Ambivalence" means the simultaneous existence of contradictory or antagonistic emotions or attitudes (for example, love and hate) toward the same person

[2] For a definition of repression, see Chap V

CHAPTER XXVI

THE OPINION-POLLING TECHNIQUE AS USED IN A STUDY OF THE EFFECTS OF BOMBING ON JAPANESE MORALE

Introduction

The sensational failure of the public-opinion polls to predict the election of Harry Truman in 1948 brought the beanstalk growth of sampling techniques forcibly to public attention. During the period of 15 or 20 years before that date, the notion that one could tell what all of the people thought by asking some of them what they thought had developed into a flourishing and lucrative enterprise Entrepreneurs of the most varied sorts came to rely upon public-opinion polls to determine what the country would buy from them Candidates for political office wrote speeches, manufacturers changed the shape of ironing boards, movie and radio magnates discarded productions, and public relations experts mounted million-dollar campaigns, all in accordance with the decision of "the sample "

Basically, the method of the sample is one which is made use of in almost every branch of scientific investigation In order to find out the effect of a newly compounded drug on diabetes the physiologist tries it on a limited number of those afflicted with the disease The artillery officer fires a few shells from a new shipment. The chemist tests several fragments of a vein of ore-bearing rock In each case, the assumption is that if the sample is a true sample—that is, chosen without bias, completely at random—what is found out about the sample will be true of the whole also

The novelty of the sampling technique is therefore not in its principle, but in its specific application to social situations In this application, as the interpretation of the preelection polls of 1948 made clear, the technique is open to serious error How the numerous possibilities of error and distortion can be eliminated or minimized, and in general, the nature of the limitations of sampling methods in social

situations, are matters that have received a great deal of study. As an illustration of some of the techniques that have been devised for the purpose of increasing the reliability of the method, we have selected an investigation of "the effects of strategic bombing on Japanese morale" This study is considered significant because it represents a use of the method of the random sample in an especially difficult and complex situation

With the heated arguments which have been carried on as to the social value of opinion polling, the present chapter has nothing to do Nor is it especially concerned with the errors in application of method or in interpretation of results that gave rise to the gross miscalculation of the 1948 election It is the opinion-sampling method itself which is the principal subject of our study

THE EFFECTS OF STRATEGIC BOMBING ON JAPANESE MORALE[1]

PURPOSE

It was the task of the Survey to discover whether changes in the morale of individual Japanese civilians were related to the series of low- and high-level, day and night, incendiary, high-explosive, and atomic bombings of the Japanese home islands which began in earnest in June, 1944.

PRELIMINARY CONSIDERATIONS

Definition of Morale. The first step was necessarily a definition of morale, the characteristic to be measured Most authorities, according to the authors of the Survey report, agree that "morale of a group in wartime is as 'good' as its consistent long-term readiness to persevere against the enemy and against hardships, and to work together under leadership to achieve the common goals"[2] In terms of components that might be evaluated by polling techniques, the Survey considered the following as indicative of morale

1. The individual's personal willingness to go on with the war, or negatively, his war weariness, the attitude he would have toward national surrender

[1] Adapted from The U S Strategic Survey (Morale Division) *The Effects of Strategic Bombing on Japanese Morale* Washington, D C, U S Government Printing Office, 1947, pp vi + 262 Dr Burton Fisher was the director of the study and was in charge of its planning, the field operation, the analysis of the results, and the preparation of the final report

[2] *Ibid*, p 10

2 His personal acceptance of the purposes of the war and his sense of identification with the common goals

3 His confidence in the possibility of victory

4 His confidence in the ability of his military leaders to achieve victory and to protect the people from attack, his belief in the will and ability of the civilian leaders to take care of the home front

5 His feeling of group solidarity, as manifested in his conviction that all elements in the population are working together and making equal sacrifices

6 His psychological and physical well-being

In short, morale is defined for the purposes of the Survey as "confidence in victory, and social solidarity "[1]

Factors Influencing Japanese Morale. In order to determine how morale, defined in this manner, was affected by aerial bombing, it was necessary for the Survey to assess the effects of other factors which might have influenced it, such as the military and naval defeats which brought the war steadily closer to the home islands, the war weariness and privations deriving from Japan's long-drawn-out military adventure beginning with the "China incident" in 1932, the maladministration of the war effort and of the home front, United States propaganda broadcasts and air-borne leaflets, the growth of communist and other sentiment politically opposed to the government, the entry of the Soviet Union into the war, and the efforts of Japanese authorities to suppress defeatism by fostering both hope of a last-minute "divine" intervention and a determination to resist invasion In addition to such changing or growing influences, it was necessary to consider the effect upon Japanese morale of the stable political, social, and religious structure of the Japanese society

METHOD

In order to ascertain the effects of the air attacks on civilian Japanese morale, the U S Strategic Bombing Survey resorted primarily to the method of polling a random sample of the Japanese people To corroborate the results of that poll, several particularly well-informed Japanese were questioned at length, and intensive study was made of confidential reports prepared during the war by such Japanese agencies as the regular police, the special (or "thought" police), whose task it

[1] *Ibid*, p 11

was to suppress defeatist and antigovernment sentiment, and the Japanese Cabinet Board of Information The present chapter, however, is concerned only with the sampling technique

The circumstances under which the polling was carried out imposed certain handicaps and limitations on the directors of the Survey Since the study concerned the feelings and attitudes of the people during the air bombardment, the questioning had to be begun as soon as possible after the surrender of Japan and concluded with the least possible delay The longer the time that elapsed after the beginning of the occupation, the less reliably would responses mirror the changes in morale before that date Actually, the work of interviewing was completed by December 29, 1945, four months after American troops had landed on the islands, and about a year and a half after the heavy bombing attacks had begun

The time limitation on the collection of data created a space limitation as well It was necessary to minimize, as far as might be, the amount of traveling to be done by the interviewing teams and their military escorts, because of hazards in entering areas not yet occupied by United States authority As a consequence, the Survey left unrepresented about 10 million (*i e* , about 14 per cent) of the Japanese population, namely, the people residing in the eastern parts of Kyushu and on islands other than the two main ones However, since these people had been spared heavy bombing, the directors of the Survey consider that their omission does not seriously affect the results

The necessity for coping with tendencies which might bias the findings was clearly recognized The Japanese who were interviewed might be likely to try to curry favor with their conquerors or to oppose them defiantly The interviewers, as representatives of the Strategic Bombing Survey, might tend either to maximize or to minimize the effects of bombing attacks Between analysts and respondents lay the barrier of language and the incalculable possibilities of distortion produced by deep-rooted differences in culture patterns The reader will recognize in various aspects of the procedures adopted by the Survey an effort to cope with these problems

The polling method used by the Survey can be studied most readily by dividing it into four component elements (1) the selection of the population sample, (2) the actual interviews, (3) the recording of the responses, and (4) the treatment of data obtained

1. Selection of the Sample. *The first step was to make sure that the sample included a balanced representation of the major gross divisions of the Japanese people* In addition, it had to be so chosen as to permit close study of those groups of people who were particularly affected by bombing, specifically, the residents of large, industrial cities, of atom-bombed Hiroshima and Nagasaki, and of rural regions to which there had been a large migration of evacuees

To select its sample, the Strategic Bombing Survey resorted to the method of *stratification.* Instead of choosing names purely at random from a list of the entire Japanese population, *e g*, by methodically taking every thousandth name in the census list, the population was first divided into sections, or "strata," on the basis of a priori ideas as to the factors which might have had an effect upon morale, and samples were then selected from each stratum The procedure is analogous to that of the assayer who decides to test samples of ore from the top, middle, and lowest sections of a vein, rather than from a random collection of specimens representing the vein as a whole

The criteria governing the division of Japan into strata, for the purposes of the Survey, were (1) the population density of the area, (2) the extent and nature of its bombing experience, and (3) its location within the country.

The strata were of two basic types incorporated cities (*shi*, in Japanese) and rural areas (*gun*)

Strata of *shi* were established according to the following principles

1 There are four major industrial areas in Japan, each of which suffered heavy bombing the metropolitan districts of Tokyo-Yokohama, Osaka-Kobe, Nagoya, and Yawata Within the first three of these areas lie five of the six largest cities of Japan Because of its size, each of these five cities was constituted a stratum in itself, thus assuring its representation in the sample Those parts of the industrial areas lying outside these five cities were classified into six additional strata, some of which represented heavily bombed *shi*, others lightly bombed or unbombed *shi* Thus, eleven strata in all were created out of the four industrial areas

2 Kyoto, one of Japan's six largest cities, which lies outside the major industrial areas and was very lightly bombed, was made a stratum in itself

3. Nagasaki and Hiroshima, together with the adjacent rural areas

in which evacuees from those atom-bombed cities took refuge, were constituted separate strata

4 All cities of over 100,000 population, not already accounted for, were incorporated into one or another of six strata, according to their size, the extent to which they had been bombed, and their location in Japan

5 *Shi* of less than 100,000 population were classified into 11 strata, according to the extent and character of the bombing they had undergone, their location in Japan, and their rate of population change during the period 1930–1940 Population change during this decade was chosen as a criterion for the establishment of strata on the supposition that it might be related to any special characteristics of recently developed industrial regions

Whenever there was doubt as to which stratum a given *shi* should be assigned to, first consideration was given to the degree of its bombing experience, second to its size, and third to the region in which it was located

Rural areas were divided into strata according to the following principles

1 Three rural strata were made up of the *gun* areas surrounding the Tokyo-Yokohama, the Nagoya, and the Osaka-Kobe industrial regions These were areas in which great numbers of the nearby urban residents had sought haven

2 Nine additional rural strata were made up according to population density, the extent of bombing, and location within Japan *Gun* of a population density below 140 persons per square mile were not classified into strata and are therefore not represented in the sample

In all, 31 strata were created from the Japanese urban areas and 12 from the rural districts The populations of the urban strata varied from 300,000 to 600,000, while those of the rural strata varied from 2,000,000 to 4,000,000 Hence, though the population of Japan is about one-third urban, the average number of persons included in each urban stratum was only one-eighth the average number in the rural strata This discrepancy, which might seem to produce an overrepresentation of the urban population in the total sample, is justified by the directors of the Survey on the ground that the urban areas suffered almost all of the heavy bombing and therefore required the most intensive study In calculating the frequency of opinions

expressed by the Japanese generally, the lack of balance between the proportions of urban and rural residents interviewed was redressed by appropriate statistical weighting

From each of the strata (except those which consisted of single cities), one city or rural district was chosen at random for inclusion in the sample The total number of interviews to be made was first divided between the urban and the rural populations in a ratio which made it approximately eight times more likely for an urban resident to be interviewed than for a rural resident The proportion corresponds to the population ratio between urban and rural strata described above

TABLE I

Age, Sex, and Education of the Subjects of the Sample

Education, years	16–29 years, per cent		30–44 years, per cent		45–70 years, per cent	
	Men	Women	Men	Women	Men	Women
0–5	3	3	9	11	37	61
6	8	16	23	33	17	15
7–8	43	33	45	30	29	14
9–11	34	42	13	22	10	7
Over 12	12	6	10	4	7	3
Total	100	100	100	100	100	100

The total number of interviews designated for all urban and all rural strata, respectively, was then allocated among the individual strata in proportion to their populations

The actual persons to be interviewed were chosen at random from census lists and other population records by sampling teams which visited each of the 43 points selected to represent the 43 strata

Table I above shows the constitution of the entire sample in terms of age, sex, and education

Interviews usually took place about two weeks after the sampling teams had done their work The only persons on the lists who were exempted from the interviews were members of the armed forces (since the Survey was assigned the task of studying civilian morale only), those under sixteen or over seventy, the seriously ill, demented, or otherwise unfit, and the institutionalized Interviewers were not

always able to locate all the persons listed, since some had moved away or could not be found However, the interviewers were expressly forbidden to substitute other persons, and they were required to make every effort to trace and interview missing ones The purpose of this rule was to prevent any possible bias which might affect the random character of the sample The interviewer, had he been allowed to substitute respondents of his own choice for those on the list whom he could not locate, might have emphasized in his selection people of stable residence, or those whose accents he readily understood, or men, or women, or some other category The result would have been an overweighting of the sample in one direction or another

A total of 4,075 persons was designated by the sampling teams, of whom 2,523 were in cities, 1,189 in rural areas, and 363 in areas hit by atomic bombs In all, 3,135 of these were actually interviewed

2 **The Interview.** The selected sample of Japanese civilians described above was questioned by members of ten teams, each consisting of nine interviewers on the average Initial contact with the person to be questioned was made by a Japanese-speaking officer who was not of Japanese ancestry This was done to avoid arousing suspicion that reports of the interview would fall into the hands of the Japanese "thought police," an attitude that might have developed had the respondent believed that the program was under the control of his countrymen The actual questioning was carried on by American citizens of Japanese ancestry (Nisei), apparently because it was impossible to recruit a sufficient number of linguistically qualified people who were not of Japanese origin, to man the teams Few of the questioners were "ideally qualified" for the task, according to the Survey report To compensate in part for their lack of professional training for the job at hand, the interviewers attended a three-day course of lectures, and they held at least two practice interviews before going into the field During this training period, recordings of the practice interviews they had made were played back to them, discussed, and criticized Other means used to maintain interviewing standards included precise and detailed instructions to the interviewers and, while the survey was in progress, visits to the teams by a group of roving experts The work of each team was under the direct supervision of a trained social scientist

At the beginning of the interview, the following formula was used

in order to "structure" the field, i e., to set the person interviewed in the proper frame of mind.

I am Mr (name of interviewer), representing the American government We are much interested in the wartime experiences (or conditions) and present conditions of the Japanese people In this connection we are interviewing people of various classes, ages, and occupations, both men and women We would be grateful, therefore, if you would answer a few questions Please be assured that what you say here will be used only by the American authorities and will be released to no Japanese person [1]

When it appeared advisable, paraphrased versions of the formula, or of parts of it, were used to reinforce the "structuring" in the course of the interview The interviewer was urged to encourage answers by respondents in terms of their personal experiences and attitudes, to seek for the reasons that lay behind the attitudes, and to make sure, as far as possible, that the answers were made with reference to that time in the past which most of the questions concerned It was emphasized that the interview would not serve its purpose if it produced only "yes," "no," or simple factual answers

The avoidance of "yes," "no," and simple factual answers clearly differentiates the method of the Morale Survey from the method employed by many commercially sponsored opinion polls However, it creates serious difficulties in the analysis and statistical treatment of the responses On the basis of such answers as the Survey demanded, it would be impossible, for example, to calculate what percentages of the total population declared that their morale was, or was not, affected by bombing Defenders of the Morale Survey method claim, however, that the procedure employed avoids a spurious objectivity in estimating opinion, an "objectivity" that is arrived at only by forcing responses into a few rigid patterns predetermined by the polltaker

The insistence of the directors of the Survey upon avoiding such rigid patterns is shown by the way in which the series of questions was arranged The question series began with queries which required little thought to answer and which were designed to put the respondent at his ease Questions eliciting the expression of attitudes concerning morale followed However, use of the words "air raid" and "bomb-

[1] *Ibid*, p 167

ing" appeared only in questions posed toward the close of the interview. The reason for this arrangement of questions was the desire to avoid suggesting that the respondents answer questions in terms specifically of the air attacks Such suggestions might prejudice the very findings which the Survey was assigned to discover

Much care went into the wording of the questions Prepared first in English, the questions were translated into colloquial Japanese by an analyst of Japanese ancestry who was familiar with contemporary Japanese speech They were then retranslated into English and compared with the original version A number of changes were made following preliminary test interviews The English version of the questions which follows is a literal translation (and therefore unavoidably awkward) of the series as it was given

1 In general, how are things going with you now?

2 Do you feel you are better or worse off now than you were during the war?

3 What things worried you most during the war? Any other worries?

4 What sort of work were you doing, from the beginning of 1945 to the end of the war?

5 How was your working capacity during this period as compared with other years?

6 How were your working conditions during this period? [To be asked only of those gainfully employed]

7 Now, we were talking a little while ago about what you were doing from January 1945 to the end of the war How many working days were you absent from your work during this period? [To be asked only of those gainfully employed]

8 What prevented you from going to work on those days? [To be asked only of those gainfully employed who missed work days in 1945]

9 During the war, what did you think was Japan's greatest strength in waging the war?

10 During the war, what did you think Japan's greatest weakness was?

11 In regard to the way your leaders conducted the war, what did you think of it during the war?

12 In regard to the way your leaders took care of the home front welfare, what did you think of it during the war?

13 How did you feel about the changes in government during the war, at the time the changes occurred?

14 Did the people's attitudes and conduct toward each other change during the war?

15 Did you think that all kinds of people in Japan suffered alike in the war?

16 As the war wore on, did you ever begin to have doubts that Japan would win?

17 When did you first feel certain that Japan could not attain sure victory?

18 Did you at any time during the war come to a point where you felt you could not go on with the war?

19 How did you feel when you heard that Japan had given up the war?

20 In regard to the policies taken by occupation-troop headquarters, how do you feel things are working out?

21 Now that the war is over, how do you think you and your family will fare in the next 2 or 3 years?

22 In your opinion, what changes should occur in Japan in the future?

22*a* What about the Emperor?

23 During the war, what did you think would be in store for you and your family, if Japan lost the war?

24 Did you know about American propaganda leaflets which were dropped during the war?

a What were the leaflets about?

b What did you think of it (them)?

25 During the war, did you ever hear about any anti-Japanese radio broad casts?

a What did you hear?

b What did you think about it?

26 During the war, did you think that your home town would be bombed? Or did you think it would be spared?

27 During the war, did you think that Japan would be bombed or did you think it would be spared? [To be asked only of those who did not believe their home town would be bombed, in reply to question 26]

28 When the American planes bombed Japan, on which side did you feel the responsibility lay?

29 How did you feel about the Americans, during the war?

30 During the war, what did you think about the way the newspapers and the radios described the air raids on Japan?

31 Did you ever hear about the Americans announcing they were going to bomb cities before they actually did? (What did you think about it?)

32 What do you recall about the first time American planes flew over Japan? (What did you think about it?)

33 In your opinion, how well was your home town protected against air raids?

34 What did you think about the atomic bomb?

35 What bombing experiences have you personally had?

[Questions 36 to 41 to be asked only if respondent lived in a bombed area during a bombing period]

36 Can you tell me more about your experiences? (Tell me what happened, what you did, how you felt)

37 What kind of bombing do you think is worse—day or night?

38 What kind of bomb do you think is worse—incendiary or explosive?

39 Were you more and more afraid as the raids continued, or did you get used to them?

40 How good were the special measures and welfare services after the raids?

41 How much help did the people who were not bombed give to those who were?[1]

3. The Record. Each interviewer took full notes in the course of the interview As soon as possible thereafter he wrote up his report Sound recordings were made of about one in every seven of the interviews Substantial excerpts from two of the interview reports follow.

SAMPLE INTERVIEW 1

Personal Data Housewife, 65 years old Four years of schooling Religion, Sect Shinto Interviewed in suburb of Nagasaki, November 16, 1945

Responses

Q In general, how are things going with you now?

A The problem that is uppermost in my mind is the food situation, but as my husband and I are old we don't need too much—the rationing is pretty slim but we are both around 70 years old so we haven't much more time to live We have a niece living with us that adds to our comfort—I worry about my husband because he is partially invalid I'm relieved the air raids are over, that was a strain on my nerves—especially trying to help my husband down to the shelters

Q Do you feel you are better or worse off now than you were during the war?

A I feel pretty good now (Why?) Well, the raids are over for one thing and my husband will become better, I hope During the night when it rains it's bad for him to be in the shelter We haven't really too much to worry about We've lived a full life so it doesn't matter what happens to us now—I'm not as bad off as those with 2 or 3 children that have to worry about the food rationing

Q What things worried you most during the war?

A My worry was for my husband It was 3 years ago when he was attacked with paralysis and now one side of his body is lightly paralyzed When there were air raids I had to carry him down to the shelters—sometimes when the raids were too often I used to cover him up with quilts and go to the shelter Then I worried the most 'cause I was afraid he would be hurt from some debris or bomb

Q What sort of work were you doing, from the beginning of 1945 to the end of the war?

A I was a housewife—I'm old now so I can't go out to work—my husband works in the post office and my niece works in a factory which helps us to get along

Q How was your working capacity during this period as compared with other years?

A There was no change in my capacity I did the same old housework—and my health was good so I tried to run the house as before—the only difference was the lack of food that cut down the meals

Q During the war, what did you think was Japan's greatest strength in waging the war?

[1] *Ibid*, pp 162–164

A I thought that our spirit, which was to fight to the end, was our strength. The soldier will also fight to the end and the people will back him to the limit Also, I heard constantly on the radio that our Air Force and Navy was stronger than America's and I believed that—we also brought out all our idols to pray to them for strength to wage war against America

. . . .

Q In regard to the way your leaders took care of the home front welfare, what did you think of it during the war?

A At times I hoped for more services and welfare, it wasn't too much but the leaders were handicapped because they didn't have the material to aid the people The rationing was a little hectic and also I suppose the leaders with money bought food from the black market—but also others did too

.

Q. Did the people's attitudes and conduct toward each other change during the war?

A Of course they would change—everyone became a little tense with nervousness Each one was worrying about food and how to feed the family I guess it was natural for them to worry about themselves, but we also tried to aid the war by obeying the rules

Q Did you think that all kinds of people in Japan suffered alike in the war?

A I don't believe everyone suffered alike—the farmers and those above the common people had more to eat—the upper class could buy in the black market while those without money had to depend entirely upon rationing—people with children suffered the most

Q As the war wore on, did you ever begin to have doubts that Japan would win?

A I had some doubts every time we were raided I always thought if airplanes could fly over Japan we would have to fight hard—so when I heard about the Doolittle planes over Tokyo, I thought for a moment that we might lose if we didn't work and fight hard

Q When did you first feel certain that Japan could not attain sure victory?

A I was only certain when the war ended—I was not sure until it ended I listened to the radio and it seemed as if we were doing all right—of course if it wasn't for the atomic bomb the government would not have surrendered

Q Did you at any time during the war come to a point where you felt you could not go on with the war?

A No I felt downhearted and scared every time the planes came over, but I never thought I would quit fighting or praying for victory

Q In your opinion, what changes should occur in Japan in the future?

A That I can't say—I can't think that deeply There should be changes I guess, but I don't know what

Q What about the Emperor?

A He should be kept for the sake of the people—he was never wrong—he was the one who ended the war—I believe no one should touch our Emperor

Q During the war what did you think would be in store for you and your family, if Japan lost the war?

A I always thought we would win but after the surrender rumors began to fly that the Americans would enslave the women and shame them and all the young girls left for some place also But in a week they returned and I heard they felt foolish upon returning.

Q When the American planes bombed Japan, on which side did you feel the responsibility lay?

A I believe the responsibility lies with the Americans—war is war and soldiers must fight soldiers but to kill innocent children and people is bad—why, over at my sister's place in Yamanishi machi, they bombed all the residential districts and completely neglected the military points which were on the other side of the tracks—that is inhuman Also the use of the atomic bomb was inhuman—all those lovely girls being cremated by the use of such a bomb!

Q. How did you feel about the Americans, during the war?

A I thought they were inhuman—when they were killed, I was happy, when any of our soldiers were killed, I cried At Okinawa my husband's two brothers died. They told me that Americans were savages, just wanting to kill and kill

Q During the war, what did you think about the way the newspapers and the radios described the air raids on Japan?

A They reported fairly well Of course sometimes I felt that it was colored because they said no planes were lost but I knew that some must have been lost in the battle

Q. What did you think about the atomic bomb?

A It was horrible I saw a bright light and then windows smashed and everything began to fly around It was around 11 00 AM My husband was standing outside and I was bathing him when it happened He was all naked and we were astounded because just the flash and then the flying debris My husband was cut on the face and head by flying glass, but I was fortunate

Q What bombing experiences have you personally had?

A. Only the atomic bomb's concussion—no other experiences in actual bombing—the atomic bomb was terrible—the people were burned and the town was burning after the flash—people were running toward our place with terrible burns (tears in her eyes) That night they slept on the roads everywhere—some collapsed during the day due to the effect of burns People would stop by and ask for water which was the most urgent need of these people They were so upset that they couldn't think of food It was a horrible night—crying and screaming I can't describe the burns (wiping her eyes) that were on these people and the odor of burning flesh was in the air It was so awful you have to see it before you can actually describe or even talk about it—it's hard to comprehend Some father, with his entire family dead, would be yelling to die so that he would not have to live alone [1]

[1] *Ibid*, pp 217–220

SAMPLE INTERVIEW 2

Personal Data Man, 25 years old, single Welder in aircraft parts plant Interviewed in Osaka, November 20, 1945

Responses

Q In general, how are things going with you now?

A I'm living with my Dad in the basement of a building Just the basement is left, the rest of the building was burnt down in the air raids of August Dad is paying the rent monthly by giving the landlord 10 cigarettes out of his rationed amount (90 cigarettes per month) Mom took my three younger brothers to evacuate in the country (Hyogo prefecture) and I miss her very much Not knowing how to economize on household expenses, Dad and I are having a pretty tough time to make ends meet I wish mother was back here to see and take care of us Water seeps into the basement after a rain and rises sometimes to about a foot and a half. It's very damp and filthy there and I know it's not good for our health, but we can't do anything about it cause we have no place to go, and in the first place we don't have the money to move

Q Do you feel you are better or worse off now than you were during the war?

A I think it's worse off now During the war, we had a somewhat easier time to make our living Our rice ration amount was 2 go, 3 shaku instead of the present 2 go, 1 shaku and we were able to get more fresh vegetables too I haven't tasted vegetables for about 4 months now People whose houses were not bombed don't know the real feelings of us who lost everything in the air raids They look upon us like we are beggars or bums and I don't know why I feel very small

Q What things worried you most during the war?

A What worried me most were the continuous air raids After all, I like to live and it is natural that I didn't want to be killed by the bombings

Q What sort of work were you doing, from the beginning of 1945 to the end of the war?

A I'm a welder at Hisaeda Bros Aeronautical and Industrial Company, manufacturers of aeroplane parts and accessories Products were delivered to Kawakami Aircraft Company I worked from 7 30 AM to 6 PM making 1 50 yen

Q How was your working capacity during this period as compared with other years?

A It was getting lower each day due to lack of food We've tried to increase the efficiency by working every day but we couldn't keep it up Our resistance couldn't keep it up Our resistance couldn't stand the pace

Q During the war, what did you think was Japan's greatest strength in waging the war?

A I learned through the press, radio and the president of our company that we had the unique and incomparable Kamikaze Corps They were harassing the enemy very much

Q During the war, what did you think Japan's greatest weakness was?

A. Black market racketeering I should say that 7 out of 10 persons were unpatriotic and were dealing more or less behind our backs It was disgusting

Q Did the people's attitudes and conduct toward each other change during the war?

A Stealing and robberies became numerous Clerks in the bank became arrogant and unkind I've noticed more among the women I don't know why Streetcar operators (women) would cuss up and down to old men or women and sometimes it made me so mad that I felt like punching her nose

Q Did you think that all kinds of people in Japan suffered alike in the war?

A I've seen directors of companies and government officials so drunk that they could hardly walk and I knew that they were leading a life of luxury A guy couldn't get drunk unless he had enough to eat, I think Merchants usually have something in their hands to barter with, but not us All we had to do is to say to ourselves that it couldn't be helped cause we weren't born rich or well-to-do

Q When did you first feel certain that Japan could not attain sure victory?

A When the B-29s would come over our city boldly, by the hundreds in daytime, and would not meet any opposition, I knew then that we were sunk

Q Did you at any time during the war come to a point where you felt you could not go on with the war?

A People used to say "The hundred million would prefer defeat to dishonor," or "shoot the works," but I doubt if half of the people were thinking that way In my opinion I can't die in honor unless my stomach is full

Q How did you feel when you heard that Japan had given up the war?

A I learned the news by reading the paper that night of August 15th I felt miserable and wretched because what I did and endured these long years of sacrificing burst like a bubble I couldn't sleep that night I was broken hearted, and still I couldn't cry

Q In your opinion, what changes should occur in Japan in the future?

A We should forget that we had a war once with America Promote and encourage importing and exporting

Q What about the Emperor?

A He should be left on the throne He is a living god to me sometimes, and I like to think that he is a human as we are sometimes It puzzles me so much that I can't make up my mind which to believe—god or human Maybe we have thought him a god too much

Q During the war, what did you think would be in store for you and your family, if Japan lost the war?

A We were told by the radio and press that males—from babies to 65 years old—would be murdered, and all the women and girls would be molested I believed it

Q What do you recall about the first time American planes flew over Japan?

A. When I learned through the press that the first American planes flew over Tokyo very low and machine-gunned several hundred public school children, it made me boiling mad I was very glad to hear that one of the planes was knocked down

Q In your opinion, how well was your home town protected against air raids?

A It is like a toy I feel very foolish to think that I've spent considerable time in air-training (practice bucket-relaying) Most of our air-raid wardens weren't there when actual bombings occurred Can't blame them, because it's too terrifying to be in the midst of it

Q What did you think about the atomic bomb?

A Even a small explosive can do a lot of damage When I learned that a single bomb has a destructive power equivalent to 2,000–50,000 bombs, it made me shudder with fear On the other hand, I realized how far back we were behind in science to keep up with the rest of the world

. . .

Q Can you tell about your [bombing] experiences? (Tell me what happened, what you did, how you felt)

A It sounded like a heavy shower pouring down I ran into the shelter and stayed in there I found out that my home was just a ball of fire when I came out The sky was full of black smoke and it was like a dark night I moved into a shack which was saved from burning and we had to borrow even chopsticks from the neighbors, as all our belongings were gone I was awake all night, feeling miserable and lonesome

.

Q How much help did the people who were not bombed give to those who were?

A All they said was "We are sorry for your misfortunes" and we didn't receive any help from anyone, anywhere [1]

Complete interview reports of this character were collected and forwarded to Swarthmore College for analysis by a technically trained staff It was the task of this staff to prepare a system of classification adequate to accommodate the many shades of opinion which the respondents expressed under the stimulus of the questioning On the basis of this classification system, cards were punched and machine tabulators were used to obtain statistical data

4. Treatment of the Data. For the most part, the results of the investigation are given as they issued from the machine tabulators employed One procedure used in putting the data into usable form merits special description because of its interest from the viewpoint of method

The attempt was made to construct an index which would provide

[1] *Ibid*, pp 221–223

a rough over-all quantitative measure of morale The method used to accomplish this was as follows. Four members of the Morale Survey analysis staff independently listed the questions the answers to which they thought would be especially significant as indicators of morale A majority of the judges agreed on 19 questions Responses to these questions were then divided into high-morale and low-morale types A random selection of 163 interviews was specifically scored for these 19 questions, and an analysis made of the 29 cases at the high end of the morale distribution and the 29 cases at the low end The analysis showed that of the 19 questions on the trial list, 7 were conspicuous in their ability to discriminate between the extremes of the distribution These were questions 11, 12, 15, 16, 17, 18, and 19, given above (It should be noted that none of these questions involved the use of the terms "air raid," "bombing," or the like) The Morale Index was constructed on the basis of answers to these 7 questions, one point (positive or negative, as appropriate) being allotted to each answer The range of the Index for any individual, therefore, was from +7 for highest morale to −7 for lowest

RESULTS

Since the primary interest of the present chapter is in method rather than in results, only a few of the salient findings of this sampling of Japanese opinion are reported here In summary of those findings, as confirmed by other methods of ascertaining Japanese attitudes, the Survey makes the following statement as to the effects of bombing on Japanese morale

At the time of Pearl Harbor the Japanese people were a little weary of the China war and were not spoiling for a fight with the United States Their first reaction to the news of war was apprehension, but in the wake of the early Japanese victories their spirits rose markedly Thereafter, and especially after the loss of Saipan, their morale began to disintegrate The process was one in which an accumulation of prolonged war weariness, social unrest, increasing consumer shortages (especially of food) and a succession of military reverses weakened the will to resist Then air attacks brought direct and immediate pressure on large segments of the population, and morale abruptly went into decline

Analysis of an important component of morale—confidence in victory—indicates that once the decline set in, in the latter part of 1944, morale cracked at an ever increasing rate Military reverses and air raids were said by the Japanese to have been the most important factors in causing them to doubt victory or to become certain that Japan could not win Consumer shortages were relatively

much more important in making individuals feel unable to continue fighting than in causing them to feel uncertain of victory

The importance of the air attacks in depressing morale is indicated by the fact that Japanese said they were

The most important single factor in causing them to have doubts of victory

The most important single factor in causing them to feel certain of defeat

The most important single factor in making them unwilling to continue the war

Their greatest worry during the war, and the thing which made most of them happy that the war was over

Supporting morale were a number of factors from which the Japanese drew strength to continue, namely

Fear of the consequences of defeat

Faith in the "spiritual" strength and invincibility of the nation

Obedience to and faith in the Emperor

The black-out of information about the war

Despite these, however, morale did fall and deterioration of the social fabric became general People became critical of their leaders and lost confidence in one another Even though the unity of the nation was falling apart, people were not able to organize for revolt, they simply became more and more obsessed with finding individual solutions to their own severe and urgent personal problems [1]

To support the contention that bombing was followed by a precipitous break in Japanese morale, the charts reproduced below (Figs 51 and 52) indicate that doubt as to the possibility of Japanese victory and a feeling of personal unwillingness to go on with the war underwent a sharp increase from the time of the first large-scale bombing of Japanese factories on June 15, 1944

Figure 51 shows that although only 10 per cent of the population doubted the possibility of victory in June, 1944, the proportion of doubters increased to more than 80 per cent in less than 15 mos Figure 52 shows that personal unwillingness to continue the war increased in similar fashion during that period However, this unwillingness developed more slowly than did doubt as to Japanese victory, and it never characterized so large a proportion of the population Evidently a great many people were willing to go on with the war, even though they were no longer confident that their country would win

These charts show a time relationship between the beginning of heavy bombing and the accelerated growth of attitudes indicating

[1] *Ibid*, p 1

deterioration of morale. But the existence of a time relationship does not necessarily mean that there was also a causal relationship. Coincidentally with the first major bombings, the island of Saipan fell to the forces of the United States, and the Tojo cabinet, under which the war had started, resigned. Conceivably it was events of this kind, rather than the bombing, or in addition to the bombing, which caused
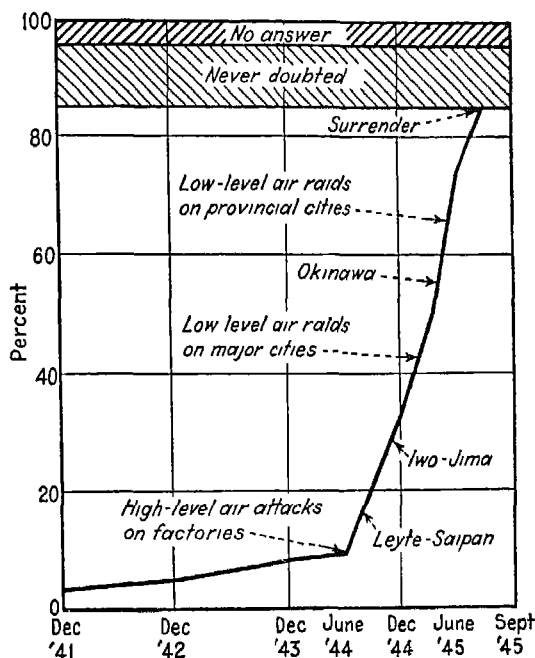
FIG. 51. Growth of Doubts of Victory

This chart shows the percentages of Japanese who said that they began to doubt victory, at various stages of the war. The chart is based on answers to the following questions: "As the war wore on, did you ever begin to have doubts that Japan would win? When was that?" (This is No. 16 of the question list, followed by the request to specify the time to which the answer referred.)

the break in morale. These possibilities can be examined by referring to Table II, which shows what reasons were assigned by the Japanese respondents themselves for their doubts of the achievement of victory by the Japanese.

The table shows that although only about one-third of those who questioned the possibility of Japanese victory stated that the air attack was a reason for their doubt, this figure somewhat exceeds the per-

centage of persons giving "military losses and reverses" as a reason, and far exceeds the percentage naming any other cause Furthermore, tabulation of the responses given by those who conceded that they had become personally averse to the continuation of the war yields similar results Thirty-five per cent ascribed their unwillingness to the air
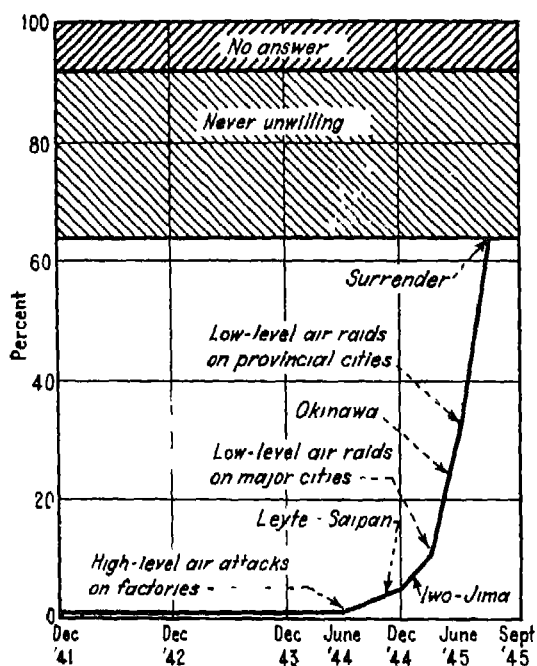
FIG 52 Growth of Unwillingness to Continue the War

This chart shows the percentages of Japanese who said they were unwilling to continue fighting, at various stages of the war The chart is based on answers to the following questions "Did you at any time during the war come to a point where you felt you could not go on with the war? When was that?" (This is No 18 of the question list, followed by the request to specify the time to which the answer referred)

attacks, including the atomic bombing, whereas all other reasons cited were given by far smaller proportions of the group

Another method of ascertaining the effects of bombing was a comparison of the morale, as determined by the Morale Index scores, of respondents in areas which differed as to the extent of the bombing to which they had been subjected This comparison is presented in Table III

Although in general the findings by this method are in the expected direction, the differences among the respondents in the various areas are not very great and by themselves do not furnish strong support for

TABLE II

Percentages of Respondents Giving Various Reasons for Doubting Japanese Victory

Doubted victory	*Percentage*
Because of the air attack	34
Because of military losses and reverses	28
Because of knowledge of shortages of war materials	7
Because of consumer shortages	5
Because of belief in greater strength of enemy, generally	5
Because they always had doubts of possibility of victory	3
Because of miscellaneous, or unspecified reasons	14
No doubts of victory	
Never doubted Japan's victory	11
No doubts indicated, but later felt certain of Japanese defeat	2
No answer	4
	113[1]

the designation of air bombardment as the principal demoralizing factor. However, the Survey points out that by the time the interviews took place many persons had been evacuated from the major

TABLE III

Morale in Relation to Experience with Bombing

Bombing strata	Had relatively low morale, per cent	Had relatively high morale, per cent
Large cities, heavily bombed, high destruction	56	44
Tokyo	50	50
Smaller cities, heavily bombed, high destruction	51	49
Smaller cities, heavily bombed, light destruction	46	54
Lightly bombed and unbombed cities	47	53
Rural communities	51	49
Urban evacuees	61	39

bomb-target cities Those who remained in the heavily bombed areas, therefore, probably represented a heavy concentration of people who, for a variety of reasons, would be likely to have had high morale

[1] The percentages add to more than 100 because some respondents gave more than one answer.

This hypothesis is strengthened by the frequency of markedly low morale among evacuees from bombed cities (see Table III) However, the relatively small differences in level of morale, as inferred from the Morale Index, of people having different degrees of bombing experience should remind us again not to overlook the effects on morale of the general war situation, as well as of specific factors other than bombing, *e g* , shortages of essential commodities, military reverses, and political upheavals

Concerning the effects of the atomic bombs, data from residents of the Hiroshima and Nagasaki areas show that although this weapon did impair the morale of many persons, it did not have the universally demoralizing effect that it often is supposed to possess In fact, comparison of the findings in two critical measures of morale for the region subjected to atomic bombs and for the rest of Japan (Table IV) shows

TABLE IV

Percentages of Respondents Asserting Absence of Doubts of Victory and of Personal Unwillingness to Continue the War among Residents of (1) the Hiroshima and Nagasaki Areas, and (2) the Rest of Japan

	Hiroshima and Nagasaki areas	Rest of Japan
Never had doubts of victory	19	11
Never were personally unwilling to continue the war	39	28

that morale was somewhat higher for the former However, it may be that many of the residents of Hiroshima and Nagasaki, both of which cities had previously been spared heavy air attack, did not separate in their thinking the fall of the atomic bomb and the surrender of Japan which took place only a week later, so that their answers reflecting their morale referred to a time before the catastrophic explosions It is clear from other data that the A-bomb did cause a sharp drop in morale among many respondents from these regions For example, of people living in Hiroshima and Nagasaki who reported that they became unwilling to continue with the war, 45 per cent ascribed their discouragement to the atomic bomb, as contrasted with only 15 per cent of the respondents in the rest of Japan.

Morale among the Japanese varied according to the occupation, age, sex, and education of the individual In terms of the Morale

Index, for example, the intelligentsia (professionals, semiprofessionals, managers, and officials) proved somewhat weaker than the population as a whole, 60 per cent of this group falling in the lower half of the total distribution of the Morale Index scores Morale proved lower

TABLE V

Percentages of Respondents of Three Age Groups and of Both Sexes Who Stated that Group Unity Had Been Weakened, that Suffering Had Been Unequally Distributed, and that They Were Never Personally Unwilling to Go on with the War

Age group	Weakened group unity		Inequality of suffering		Never personally unwilling to go on with war	
	Men	Women	Men	Women	Men	Women
16–29	54	49	48	47	31	35
30–44	54	44	50	40	23	28
45–70	41	26	40	25	26	24

among the young and middle-aged than among those over forty-five, and lower among the men than among the women Table V above indicates the percentages of men and women of various ages (1) who said that Japanese group unity had weakened during the war, (2) who

TABLE VI

Percentages of Respondents of Five Educational Levels Who Stated that Group Unity Had Been Weakened, that Suffering Had Been Unequally Distributed, and that They Were Never Personally Unwilling to Go on with the War

Education, years	Weakened group unity	Inequality of suffering	Never personally unwilling to go on with war
0–5	26	24	20
6	36	33	23
7–8	46	42	30
9–11	56	57	35
Over 12	68	62	42

stated that suffering had been unequally distributed, and (3) who asserted that they, personally, had never been unwilling to continue the fight against the enemy

An ambiguous picture is presented when the data are analyzed in terms of the education of the respondents As appears in Table VI

above, the more schooling a Japanese had, the more ready he was to believe that the war had weakened those pseudofamilial ties which bound each Japanese to all others of his nation, and the more convinced he was that the national trials had been borne unequally Nevertheless, the table also shows that the better educated Japanese was the more likely to want to fight on The Survey suggests a reason for this apparent inconsistency. Although the better educated Japanese was more likely to have been informed of his country's military defeats and its withering chances of victory, he was usually wealthier than the majority of his countrymen, had suffered less from shortages, and had more to lose in case of defeat

Discussion

Obviously, without any intended cynicism, there is no sure way of testing the validity of the Morale Survey except by repeating the "experiment"—bombing followed by survey—a resort hardly to be recommended However, the results, on the whole, appear to be valid, especially since they agree with statements made by individual Japanese possessing special sources of knowledge and with records of Japanese agencies concerned with Japanese opinion

This problem of validation of results is one which besets almost all opinion polling, even when it is feasible to "try the experiment again" Those who conduct polls designed to discover which candidate a community will vote for can claim only that their findings show whom those members of the community who express opinions would have voted for had their expressed opinions been their real ones, and had they cast their ballots at the time the poll was taken What can be concluded from the ascertained fact that most of a representative group of housewives declare a preference for a certain design of ironing board? It does not necessarily follow that the same percentage of housewives want to buy ironing boards, nor that those who do will actually purchase ironing boards of this design when they finally appear in the shops

Despite limitations of this character, the scientific usefulness of opinion polling appears to be beyond question, and it would appear that the real task is to eliminate as many sources of error as possible The Morale Survey is a contribution to this task First in importance, perhaps, is its insistence upon free rather than controlled expression of opinion on the part of the respondents, that is, upon the "What do

you think about . . . ?" rather than the "Do you think that ?" kind of question. How many people who answer "yes" when asked whether they will vote for a particular candidate really mean "I'll vote for him unless he continues talking in the vein of his last three speeches"? How many people who say, "I don't know," really mean "I haven't decided whom I'll vote for, but unless X shows some gumption, I'll probably vote for Y, even though I generally don't like his views"? Such shades of opinion do not lend themselves to quick, easily and cheaply made summaries. It is clear that the restriction of answers to "yes," "no," and "I don't know" may afford only the roughest of guides to the real opinions of those questioned Hence it is difficult to determine from such answers how people really feel or what their future behavior actually will be, for example, whom they will finally decide to vote for on Election Day

However, the method of "stratification" adopted by the Survey is open to criticism on certain grounds From one point of view, it implies a mistrust of the principle of random selection as the basic method of arriving at a representative sample The polltaker who uses "stratification" seems to fear that elements in the population which he considers significant in terms of his problem may be overlooked or inadequately represented if he depends altogether on chance in his choice of those to be interviewed He therefore permits random selection to operate only within the strata he has established By this means he assures himself that the opinions expressed by people in each stratum exert an influence upon the total sum of opinions in proportion to the population of the stratum

In a situation in which time and expense are of little importance, there would be no reason for such a departure from the method of chance selection of the sample to be polled Any section of the population which constitutes a significant proportion of the whole would be correctly represented by an adequately large sample chosen purely at random What then is the justification for the establishment of strata?

In the case of the Morale Survey, the best justification is the practical consideration that the method was an economical one, economical of time and perhaps of life [1] A sample taken from the national popula-

[1] Two matters are to be recalled in this connection first, that the occupation of the Japanese Islands by the forces of the United States was far from complete at the time the investigation was undertaken, and second, that the planners of the Survey were convinced

tion at large would necessarily have included individuals living at widely scattered points Interviewing them would have required a great deal of additional travel time for the Survey's teams as well as the jeopardy of their personal safety Granted the limitation on size of staff, the result would have been a smaller total sample, or a longer interval between the end of the war and the questioning, or both It was decided, therefore, to limit the interviews to persons residing in a relatively small number of places in Japan

It may be argued also that stratification constitutes a hedge against hidden errors which might distort seemingly random procedures For the selection of a sample by chance is by no means so simple a matter as may appear at first sight Even honestly manufactured dice are likely to be a trifle "loaded" Polltakers have long recognized that making a choice of names from a telephone directory results in a sample not of the population at large, but only of that part of the population wealthy enough to subscribe to telephone service Other sources of error in sampling, however, are less easy to recognize For instance, within the telephone directory itself people whose names begin with "O" do not necessarily represent a valid sample of all the subscribers, there is likely to be an abnormally large proportion of folk of Irish origin among them The polltaker's decision as to which groups are significant in the analysis and should therefore be properly represented in the sample constitutes a safeguard against unforeseen distortion which any system of random sampling may produce

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that the validity of the results would be weakened if any considerable time elapsed between the surrender and the interviews

INDEX

A

B

C

D

J

K

Q

R